IDA

INSTITUTE FOR DEFENSE ANALYSES

# Proceedings of the NATO Radiological Human Response Subject Matter Expert Review Meeting 26 June 2008 Albuquerque, New Mexico United States of America

Julia K. Burr
Carl A. Curling
Deena S. Disraelly
Preston J. Lee
Terri J. Walsh
Robert A. Zirkle

August 2009

IDA Document D-3885
Log: H 09-001232

*The Institute for Defense Analyses is a non-profit corporation that operates three federally funded research and development centers to provide objective analyses of national security issues, particularly those requiring scientific and technical expertise, and conduct related research on other national challenges.*

**About This Publication**

**This work was conducted by the Institute for Defense Analyses (IDA) under contract DASW01-04-C-0003, Task CA-6-2281, "Revision of NATO Planning Guide for the Estimation of Battle Casualties," for the Office of the Surgeon General of the Army. The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.**

INSTITUTE FOR DEFENSE ANALYSES

IDA Document D-3885

# Proceedings of the NATO Radiological Human Response Subject Matter Expert Review Meeting 26 June 2008 Albuquerque, New Mexico United States of America

Julia K. Burr
Carl A. Curling
Deena S. Disraelly
Preston J. Lee
Terri J. Walsh
Robert A. Zirkle

# PREFACE

This document reports work performed by the Institute for Defense Analyses for the United States Army Office of the Surgeon General in partial fulfillment of the task order CA-6-2281 "Review of NATO AMedP-8 *Planning Guide for the Estimation of Battle Casualties.*" On 26 June 2008, a meeting was held in Albuquerque, New Mexico, to reach an international consensus on the radiological agent exposure human response models to be recommended for use in Allied Medical Publication 8, *NATO Planning Guide for the Estimation of CBRN Casualties* (AMedP-8(C)). Attached are the minutes and presentation slides from that meeting which constitute the record of the proceedings of that meeting.

The authors wish to thank the reviewer, Dr. Jeff Grotte for his careful review of this document, and Mr. Lucas LaViolet who edited this document.

THIS PAGE INTENTIONALLY LEFT BLANK

# CONTENTS


PREFACE ..... iii
EXECUTIVE SUMMARY ..... ES-1
I. NATO RADIOLOGICAL SUBJECT MATTER EXPERT HUMAN RESPONSE REVIEW MEETING PROCEEDINGS ..... 1
A. Purpose ..... 1
B. Attendees ..... 1
C. Meeting Summary ..... 2
D. Areas of Concurrence ..... 2
E. Recommendations/Next Actions ..... 4
F. Meeting Notes ..... 5
II. BRIEFINGS ..... 17
A. Radiological Human Response Review Overview and Objectives – *Briefing* ..... 19
B. General Human Response Modeling Concept: Radiological – *Briefing* ..... 25
C. Radiological Exposure Environments – *Briefing* ..... 37
D. Illustrative Example: Radiological – *Briefing* ..... 49
E. Proposed Radiological Human Response Model – *Briefing* ..... 61
F. Radiological Casualty Criteria – *Briefing* ..... 85
G. The German Radiation Accident Database – SEARCH – *Briefing* ..... 93
H. Radiological Review, Conclusions, and Way Ahead – *Briefing* ..... 107

THIS PAGE INTENTIONALLY LEFT BLANK

# EXECUTIVE SUMMARY

This paper provides a summary of and briefings from the NATO Radiological Human Response Subject Matter Expert Review Conference, held at the Defense Nuclear Weapons School, Albuquerque, New Mexico, in June 2008. The purpose of this one-day conference was to review and amend a casualty estimation methodology for exposure to radiological agents proposed by the Institute for Defense Analyses (IDA) for implementation in a revised version of NATO Allied Medical Publication 8 (AMedP-8(C)). The focus of the conference was on the human response component of the methodology, including severity definitions, appropriate dose ranges, and dose-based physiological system symptom progressions and injury profiles for these agents. During the conference, these elements were discussed and amended to reflect the results of current scientific research and professional opinion expressed by the participants.

This paper begins with a summary of the conference proceedings, followed by the eight briefings presented at the conference. The first four presentations were designed to familiarize the conference attendees with the purpose of AMedP-8(C) and with the proposed general casualty estimation process. The next two briefings described the technical details of the development and content of the methodology's proposed human response component for radiological agents. After these briefings, the general casualty estimation and reporting component of the methodology was presented, followed by a discussion of the German Radiation Accident Database presented by COL Densow, DEU. The final briefing was a review of the consensus points developed by participants during the conference.

This conference was sponsored by the US Army Office of the Surgeon General (OTSG) in its role as the Custodian of AMedP-8.

THIS PAGE INTENTIONALLY LEFT BLANK

# I. NATO RADIOLOGICAL SUBJECT MATTER EXPERT HUMAN RESPONSE REVIEW MEETING PROCEEDINGS

## A. Purpose:

The purpose of this meeting was to review the proposed human response model for estimating casualty effects resulting from exposure to radiological insults – radiological dispersal devices or fallout – focusing in particular on the estimation of dose, as well as the severity definitions and the dose-based injury profiles. The model is proposed for potential implementation in NATO Allied Medical Publication 8 (AMedP-8).

## B. Attendees:

Canada

- CDR Ian Torrie, Health Services Operations
- Dr. Diana Wilkinson, Defense Research and Development Canada

France

- GEN Yves Chantrelle, French Army Medical Research Center

Germany

- COL Dirk Densow, Bundeswehr Medical Office
- Mr. Steven Hotop, ESG Company Munich
- Mr. Jakob Rieck, ESG Company Munich

Great Britain

- LtCol David Bates, UK Surgeon General
- Dr. David Holt, Consultant to Institute of Naval Medicine
- Dr. Robert Jefferson, Medical Toxicology Center, advisor to Ministry of Defense (MOD)

Netherlands

- Mr. Maarten Huikeshoven, Dutch MOD

United States of America

- Dr. Carl Curling, Institute for Defense Analyses (IDA)
- Ms. Misouk Choun, US Army Office of the Surgeon General (OTSG)
- Ms. Deena Disraelly, IDA
- SSgt Dixon, Defense Nuclear Weapons School (DNWS)
- MAJ Kevin Hart, OTSG

COL Lester Andy Huff, Armed Forces Radiobiological Research Institute (AFRRI)

Dr. Gene McClellan, Applied Research Associates (ARA)

COL John Mercier, AFRRI

Dr. Kyle Millage, ARA

Dr. Eric Nelson, Defense Threat Reduction Agency (DTRA)

Mr. Fred Scudiery, DNWS

Mr. James Smith, OTSG

COL Clark Weaver, J-8, Joint Chiefs of Staff, Medical Defense

CAPT Andy Woods, US Navy Bureau of Medicine (BUMED)

TSgt Wright, DNWS

Dr. Robert Zirkle, IDA

**C. Meeting Summary:**

The following presentations were given:

- MAJ Kevin Hart – Radiological Human Response Review Overview and Objectives
- Dr. Carl Curling – General Human Response Modeling Concept: Radiological
- Dr. Robert Zirkle – Radiological Exposure Environments
- Dr. Robert Zirkle – Illustrative Example – Radiological
- Ms. Deena Disraelly – Proposed Radiological Human Response Model
- Dr. Carl Curling – Radiological Casualty Criteria
- COL Dirk Densow – The German Radiation Accident Database – SEARCH
- MAJ Kevin Hart – Radiological Review, Conclusions, and Way Ahead

**D. Areas of Concurrence:**

The following areas and topics were concurred on by the Nations during the meeting:

- General points of concurrence
    - Maintain consistency with chemical, biological, and nuclear models as feasible
    - Do not model medical intervention
    - Do not include battle stress cases
- General modeling concept – human response can be estimated using specified severity levels as represented in the injury profiles
    - Nuclear irradiation progressions will be used (including changes as incorporated) for whole body absorbed doses
    - Skin (radiological) progressions will be used (including changes as incorporated)
    - Methodology for combining skin and irradiation symptoms to produce injury profile will be used as proposed
    - Include time-to-death calculation (green line)

- Dose/insult ranges were agreed to with the following corrections (updated ranges are presented below in Tables 1 and 2)
    - Radiation: as agreed to previously
    - Cutaneous: no corrections
- Symptoms systems were agreed to with the following correction
    - Rename “Contamination” as “Cutaneous” to capture both irradiation and contamination
- Symptoms descriptions were agreed to with the following corrections
    - Remove “signs” from descriptors
    - Skin (radiological):
        - Modify “Mild” – remove “redness” and “sense of heat”, add erythema
        - Modify “Severe” – skin necrosis (remove “possible”)

**Table 1. Whole-Body Radiation Dose Ranges**

| Dose Range (Gy) | Description |
|---|---|
| **< 1.25** | No observable effect in the majority of the population |
| **1.25 – < 3** | A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is > 90% unless there are other injuries |
| **3 – < 5.3** | Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{10/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and possible death |
| **5.3 – < 8.3** | Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries death may occur within 2 weeks |
| **≥ 8.3** | Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2 to 3 weeks; with other injuries death may occur within 2 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1 to 2.5 weeks or if other injuries are also present, patients may die within 6 days |

**Table 2. Cutaneous Radiological Dose Ranges**

| Dose Range (Gy) | Description |
|---|---|
| **< 2** | No observable effect in the majority of the population |
| **2 – < 15** | 2 to 5 weeks post exposure: erythema, slight edema, possible increased pigmentation; 6 to 7 weeks post exposure: dry desquamation |
| **15 – < 40** | Immediate itching; 1 to 3 weeks post exposure: erythema, edema; 5 to 6 weeks post exposure: subcutaneous tissue edema, blisters, moist desquamation; late effects (> 10 weeks) |
| **40 – < 550** | Immediate pain, tingling for 1 to 2 days; 1 to 2 weeks post exposure: erythema, blisters, edema, pigmentation, erosions, ulceration, severe pain; severe late effects (> 10 weeks) |
| **≥ 550** | Immediate pain, tingling, swelling; 1 to 4 days post exposure: blisters, early ischemia, substantial pain; tissue necrosis within 2 weeks, substantial pain |

## E. Recommendations/Next Actions:

Based on this meeting, the following additional tasks were recommended:

- Participants –
    - Provide supporting documentation, studies, & references as available
        - Holt – 2 sources
    - McClellan – dose protraction curve
    - Wilkinson – iodine source for inclusion
    - Review Skin (radiological) injury progressions with National SMEs (responses requested by 22 July 2008)
- OTSG/IDA –
    - Incorporate comments as provided for revised versions of read-aheads
        - Prepare updated injury progressions and profiles for National reviews
    - Send updated profiles out for review (responses requested by 8 July 2008)
    - Incorporate National comments as provided for updated profiles
    - Update the system symptom severity descriptions as discussed
    - Update the injury progressions and profiles as noted
    - Incorporate scaling factor for fallout case calculation (protraction)
    - Add note regarding the necessity to run simultaneous conventional casualties model
    - Incorporate inhalation action level with associated capture of wounded in action (post-radiological exposure prophylaxis) (WIA (PREP)) at 20 mSv
    - Update assumptions:
        - Add Centers for Disease Control and Prevention (CDC) assumptions for cutaneous injury

        - Change assumption to read that "activity deposited on the ground will be used to estimate activity deposited on the skin; deposition on the skin occurs by some mechanism (i.e., reaerosolization, etc)"
        - Remove "post-fallout field" assumption
        - Add statement that cloudshine dose will be neglected for fallout
        - Update dose protraction assumption to explain incorporation of scaling factor
        - Radiological dispersal device (RDD) deposition may be discontinuous; may be necessary to represent as point sources
    - Notations to be added:
        - Additional notations as discussed
        - Update the purpose statement to read: "To provide a methodology for *uniquely* estimating casualties occurring as a consequence of chemical, biological, radiological or nuclear (CBRN) attacks against Allied targets, military or civilian, to support the NATO medical planning process. The methodology is designed to provide estimates of time dependence of the incidence of symptoms by type and severity, numbers of casualties, to include numbers of fatalities."
        - Inhalation is not included because there was not enough information at the time of publication
        - In reference to the dose protraction scaling factor for fallout, include a statement regarding the rough approximation
        - Relabel "contamination activity to the skin" and remove the "H" from the equation for the equivalent dose to skin from skin contamination
        - For equation to calculate equivalent dose to skin from fallout ground deposition, use a beta-to-gamma dose ratio for a height above ground somewhere in between 100 cm and 160 cm
        - Include gamma radiation in the total value for dose to skin from fallout ground deposition
        - The need for a conventional blast model to be run concurrently with a radiological dispersal device model should be specifically noted

**F. Meeting Notes:** Presentations were given by MAJ Hart, Dr. Curling, Ms. Disraelly, Dr. Zirkle, and COL Densow.

1. MAJ Kevin Hart – <u>Radiological Human Response Review Overview and Objectives</u>

MAJ Hart began by outlining the meeting objectives, then briefly reviewed the casualty estimation concept and discussed the foundations of NATO's casualty estimation methodologies. The starting point of the human response model follows the outputs described in SD.2 – that describes what we need out of the dispersion model – where the people are, how many, their disposition, the concentration and doses they are exposed to.

He discussed the development process and the potential process for implementation. He anticipated that for NATO planning purposes, there would be a requirement to work with the

people currently working on the planning tools SABERS or MEDIC to build an implementation capability.

The stated purpose of the document is for medical planners to get what information they need: medical casualties and battlefield effects, resources, etc. If the document can be used for other purposes as well, then all the better, but the end-state customer is the medical planner.

He closed by reviewing the meeting agenda.

Participants recommended adding the word "uniquely" to the purpose statement.

2. Dr. Carl Curling – General Human Response Modeling Concept – Radiological

Dr. Curling laid out the process for developing the AMedP-8 SD.3 document, and reviewed the general human response modeling concept proposed for use in the document, including definitions, assumptions, and model limitations. The proposed human response models are described by injury profile maps – based on an explanation of symptoms severities over time, which are combined to build an injury progression map. The objective of the document is to estimate the status over time of personnel exposed to some CBRN agent. To focus on radiological, it is the number of people who are expected to be wounded or killed as a result of exposure to radiological agents following a radiological dispersal device attack or radiological fallout.

The model does not look at certain medical casualties – those who are psychological casualties although they may be expected to seek medical assistance or those who are died or injured as a result of secondary injuries.

Questions by participants included:

- Why is it necessary to have the conversion factors in this portion of the methodology instead of as an input?
    - The conversion factors are drawn from an International Atomic Energy Agency (IAEA) reference and this was an easy place to implement them.
- Will the model include inhalation?
    - Given the relatively large doses to the skin and the whole body and the relatively long time frame for internal effects, internal and inhalation effects are not believed to be significant.

Participants discussed the need to include inhalation of radioisotopes, in particular due to the chemically toxic nature of some radioisotopes. The question was raised regarding whether it would be credible to have an acute inhalation of these agents without having an acute radiological response. Participants suggested that it would be impossible to judge as there may not be enough information to estimate the quantities of stable isotopes inhaled and the associated radiotoxicity vs. the chemical toxicity. Participants concurred that it would be clearly stated that

inhalation is not included because there was not enough information at the time of publication. Participants did indicate that inhalation and/or ingestion could pose long term care issues for medical planners.

Participants recommended the use of the terms “whole body” and “organ” dose to replace effective and equivalent dose which are measured in sieverts (referenced International Commission on Radiological Protection (ICRP) Publication 103).

Participants discussed assumptions regarding skin contamination dose. Participants recommended that ground activity may be used to infer the activity on the skin. Dr. Curling pointed out that the propagation models give us the same activity on the ground. Participants further indicated that skin contamination effects depends on the portion of the body that contamination is deposited on; to assume all skin is covered is fair enough because while it may overestimate for some parts of the body, the dose will be underestimated for others.

Participants raised concerns regarding the importance of dose rate, but acknowledged that it is difficult to model. Discussion turned to the possible inclusion of a scaling factor to allow for the incorporation of dose protraction (in reference to radiological fallout only). Participants did raise concerns about the error associated with this modeling. The final recommendation was to use a scaling factor for fallout and include a statement regarding the rough approximation.

3. Dr. Robert Zirkle – <u>Radiological Exposure Environments</u>

Dr. Zirkle described the different possible routes of exposure associated with each of the two considered radiological exposures—radiological dispersal devices and radiological fallout. He then reviewed the equations for converting activity concentrations and depositions to irradiation and percutaneous doses and discussed the necessary combinations to yield whole body irradiation dose and skin organ dose. He also reviewed specific assumptions associated with the methodologies and conversion factors required for implementation (drawn from IAEA documentation).

Questions by participants included:

- Does the proposed methodology assume that all skin contamination is due to resuspension?
    - By some mechanism, the contamination on the skin equals the contamination on the ground and may include resuspension.
- Does the Hazard Prediction and Assessment Capability (HPAC) output include committed effective dose equivalent (CEDE)?
    - Yes.
- What about slant ranges?
    - Slant ranges are not considered.
- What is the rationale for excluding gamma?

    - For contamination on the skin, the methodology only considers the beta. The dose to the whole body considers the gammas.
- Does particle size have an effect on contamination?
    - One of the issues was estimating skin dose due to gamma component; it's difficult unless someone sees a way that doesn't include stochastic effects.
- Are you satisfied that these conversion factors have been properly converted?
    - These are the correct values for beta dose.

Participants discussed the need for incorporating cloudshine and groundshine doses into the percutaneous skin dose. Participants suggested that without including groundshine, the value is an underestimation of dose.

Participants continued the previous discussion of internal contamination and whether it could be neglected. Some participants suggested that medical action might need to be taken within the period of interest in reference to internal contamination cases. MAJ Hart indicated that the purpose of the document is planning for acute medical resources. Participants suggested that although the document does not consider treatment, the planner may still need to made aware of cases that would require certain treatments and allocation of resources. In response, MAJ Hart raised the question: if you got a dose high enough to give someone Prussian Blue, wouldn't the dose would show up at least on the mild response? Participants could not be certain of the answer and suggested that this discussion be left to AMedP-6 or that a threshold qualifier value be used to assign icons to a modified wounded in action (WIA) status.

The discussion continued and participants suggested that external dose is far more important than internal contamination; the population would not need to be sick, but rather would be treated presumptively. MAJ Hart recommended neglecting internal contamination for fallout and establishing a 20 mSv cutoff for RDD. Participants suggested tying the value to the ICRP annual limit.

Dr. Curling summarized the discussion stating that what we have is two different losses to the unit – one in which personnel are lost to the unit because there is a medical intervention (chelation, etc.) above this CEDE (proposed as 20 mSv) and the second is a loss to the unit due to actual injury; if there is no medical intervention, if all that's being done is an evaluation to determine whether the individuals "got it," that determination can be done at any time. If the requirement says these people require treatment, that's one thing. If instead it is determined that these people are lost because they are exposed and require investigation…that's another.

Participants, however, did not all agree with this assessment pointing out that the line commander has a decision to make and he expects people to stay; it doesn't make any sense at all to pull these people out.

MAJ Hart proposed three options for incorporating contamination:

- No one gets contaminated – too much reliance on the planner for accounting for these
- Everyone gets contaminated – 100% need some level of medical management
- Some intermediate number of people get contaminated – adjust up or adjust down, but include a large amount of error due to troop location, source term, environmental conditions, etc.

Participants then discussed the contribution of gamma radiation to skin contamination (percutaneous) dose. One participant pointed out that in the Georgian incident, gammas had very significant effects on the skin. Dr. Curling responded that in the model, anything on the skin is in the air and on the ground as well. Gamma emitters expose via the ground and the air.

Participants recommended relabeling "contamination activity to the skin" and removing the "H" from the equation for the equivalent dose to skin from skin contamination.

Participants suggested that iodine might need to be considered as a potential radioisotope as well. Dr. Zirkle pointed out that specific radioisotopes have only been identified for radiological dispersal devices.

Participants recommended the use of 7 $mg/cm^2$ as a value of skin thickness.

Participants asked why it was necessary to include contamination pointing out that an individual who knows that there is contamination would not go into the field unprotected. Further, the clinical outcomes vary depending on whether the assumption is a dose to 10 $cm^2$ or on the whole body. Dr. Curling pointed out that for skin effects, we are neglecting died of wounds (DOW) and killed in action (KIA) at this time. The assumption was that any ulceration or any overt symptom of skin damage due to irradiation should be considered on WIA status independent of the body surface that's affected.

Participants agreed that 120 cm above the ground was an acceptable height at which to estimate whole body irradiation's contribution to skin dose due to groundshine. Further, participants agreed that gamma contribution to skin dose due to groundshine is equivalent to the groundshine dose.

4. Dr. Robert Zirkle – <u>Illustrative Example: Radiological</u>

Dr. Zirkle walked through an illustrative example, describing the series of clinically differentiable dosage bands, each of which has signs/symptoms dosage maps associated with it, as well as the injury profile map which gives an overall example of how injury severity changes over time. Further, there are criteria set by the user which describe the personnel status and the times under consideration – i.e., time to reach a medical treatment facility, evaluative time period, reporting time, total time, etc. The inputs are exposures, and the estimation of casualties

follows a process to determine KIA, WIA, and DOW as applicable. Additionally, he walked through a number of specific examples to demonstrate how the model works.

Questions by participants included:

- Since the green line doesn't have time to death less than 30 minutes, could that (KIA block) just be dropped out?
    - Yes.
- How do you propose to run the fallout and nuclear methodologies concurrently? Do we add the external doses?
    - We propose to add the irradiation dose and the fallout whole body dose to increase the whole body dose and use that as the input to the fallout methodology.
- Do you consider that there will be no conventional injury with an RDD?
    - We don't have a good blast model and hope that we could run a conventional blast model concurrently.
    - Shrapnel injuries generally fall off as a function of the cube root of the yield. If you're standing next to the bomb when it goes off, you'll be a casualty, otherwise, not a conventional casualty.

5. Ms. Deena Disraelly – <u>Proposed Radiological Human Response Model</u>

Ms. Disraelly reviewed the model assumptions and then presented the symptoms, as well as the symptoms progressions and overall injury profiles over time for the radiological human response model including irradiation and percutaneous routes of exposure. The irradiation human response injury profiles and associated symptom progressions will follow the same profiles and progressions described for irradiation insults following a nuclear event.

Questions by participants included:

- Do these dose ranges/descriptions take into account cellular tissue repair? Do we need to account for protracted doses to the skin?
    - We didn't look at protracted skin doses.
    - Little data are available to suggest a response from radiation to skin by dose rate; we can make a note that dose rate is not included, but that it will be as soon as appropriate data are available.
- Is there no mechanism by which to die from radiation on the skin?
    - Individuals can die, but not within six weeks.

Participants suggested that in radiation accidents, we've seen erythema at about 2 Gy within an hour, peaking at 24 hours; this depends on dose rate and should be accounted for.

MAJ Hart recommended that the required factors and transfer assumptions from the CDC guide be incorporated into the final document.

Participants recommended changing "contamination" to "cutaneous" in tables and profiles.

Participants also recommended adding a footnote to the cutaneous dose ranges table which reads, "Both (gamma and beta radiation) are considered, but not separately."

Participants recommended the removal of "sensation of heat" from the description of Severity Level 1. Participants recommended changing the description of Severity Level 3, from "possible skin necrosis" to "skin necrosis" and, in the description of Severity Level 1, change "redness" to "erythema."

6. Dr. Carl Curling – Radiological Casualty Criteria

Dr. Curling presented the methodology for using injury profile maps to estimate casualties and other personnel status and discussed multiple levels of detail that could be considered. He recommended the specification of casualties by insult (i.e., chemical nerve agent or chemical blister agent) and severity level at time of casualty presentation.

Participants recommended the inclusion of a post-exposure prophylaxis WIA category to account for individuals requiring medical treatment associated with internal contamination.

7. COL Dirk Densow – The German Radiation Accident Database – SEARCH

COL Densow gave an invited presentation discussing the information included in and potential uses for the German Radiation Accident Database, SEARCH. The briefing focused on going back to the collected data to determine if the times of onset, etc, are supported by the data. He suggested that participants might consider, with his help, accessing the data and data mining.

The database response categories are associated with therapeutic care. There are approximately 800 cases currently in the database; not all are necessarily available for data-mining for the acute phase.

The database includes five response categories, with level 5 being the most severe. COL Densow described the symptoms associated with each level as well as the distribution across cases in each response category.

All people in the database received medical care.

Questions by participants included:

- What is "survived"?
    - This means they survived up to 100 days.
- When does the curve terminate?
    - The curve terminates when they died.

- Are doses estimated by reconstitution?
    - Reconstitution and teeth enamel, whatever they had available, and early erythema indicated which part of the body was closest to the source.

- Are there other data captured?
    - As much information as possible was captured—history of exposure, clinical data, etc. However, it is hard to tell about when injuries occurred.

MAJ Hart suggested that using this data set might allow for the possible incorporation of medical treatment into the radiological model.

8. MAJ Kevin Hart, US Army – Radiological Review, Conclusions & Way Ahead

MAJ Hart concluded the meeting by thanking participants and reviewing the areas of concurrence and taskings. (The areas of concurrence and the taskings are listed earlier in this document.) The symptom progression maps and injury profiles, as agreed upon by consensus of the SMEs at this meeting, are presented in Figures 1 through 8.

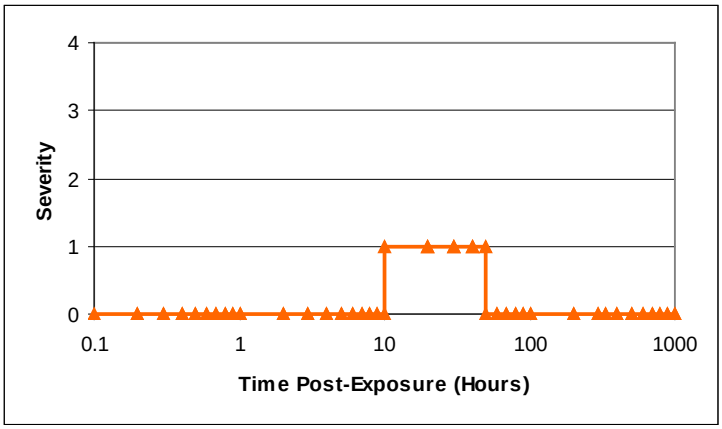



**Figure 1. Cutaneous Radiological Injury Profile for Dose Range 2 – < 15 Gy**

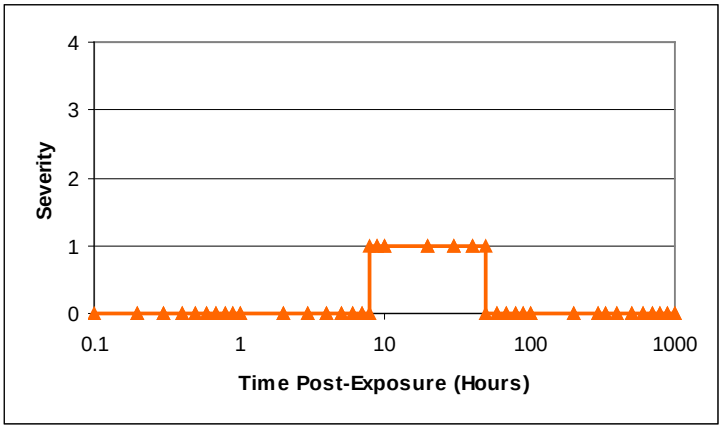



**Figure 2. Cutaneous Radiological Injury Profile for Dose Range 15 – < 40 Gy**

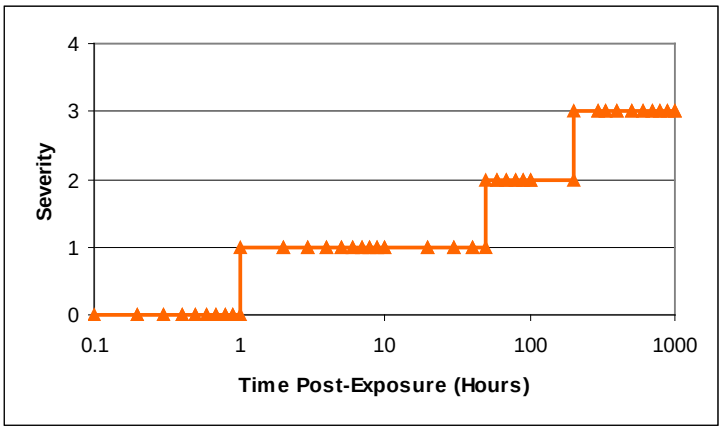



**Figure 3. Cutaneous Radiological Injury Profile for Dose Range 40 – < 550 Gy**

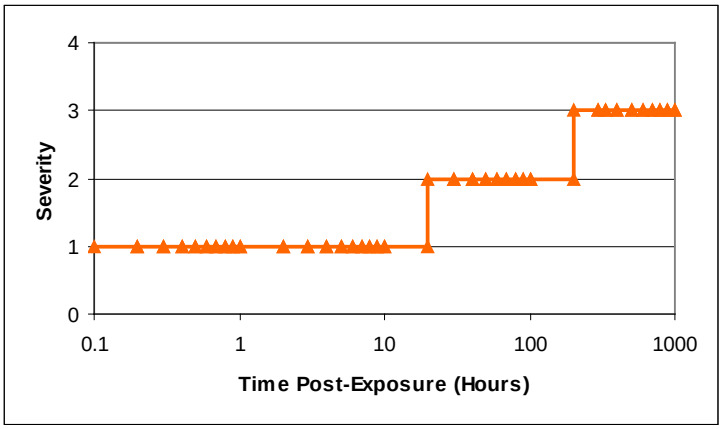



**Figure 4. Cutaneous Radiological Injury Profile for Dose Range ≥ 550 Gy**

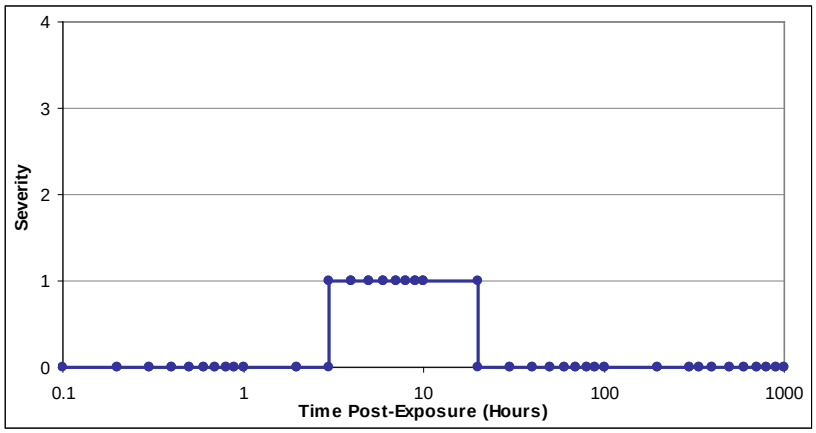



**Figure 5. Irradiation Injury Profile for Dose Range 1.25 – < 3 Gy**

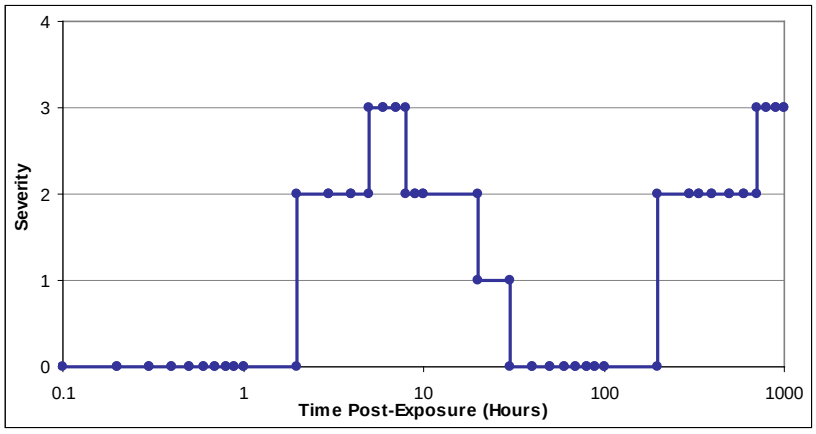



**Figure 6. Irradiation Injury Profile for Dose Range 3 – < 5.3 Gy**

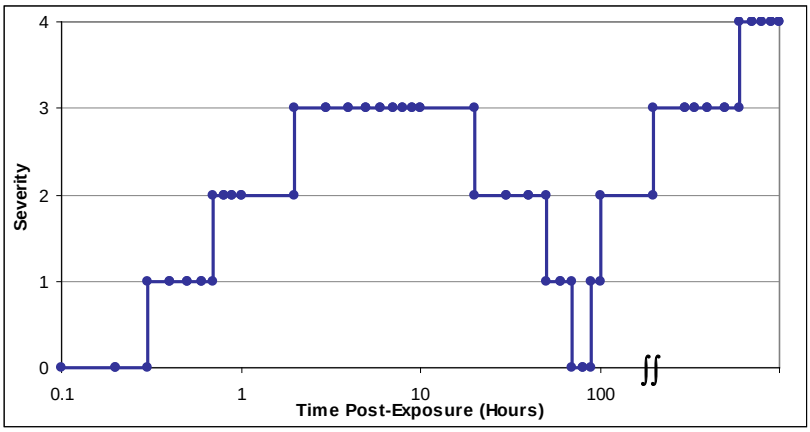



**Figure 7. Irradiation Injury Profile for Dose Range 5.3 – < 8.3 Gy***

*After approximately 100 hours, the time-component portion of the profiles should be neglected for doses in excess of 5 Gy as indicated by the "SS" marks on the injury profiles. Profiles should be followed up to the calculated time-to-death. KIA or DOW due to whole-body radiation dose should be determined by time-to-death calculations only.

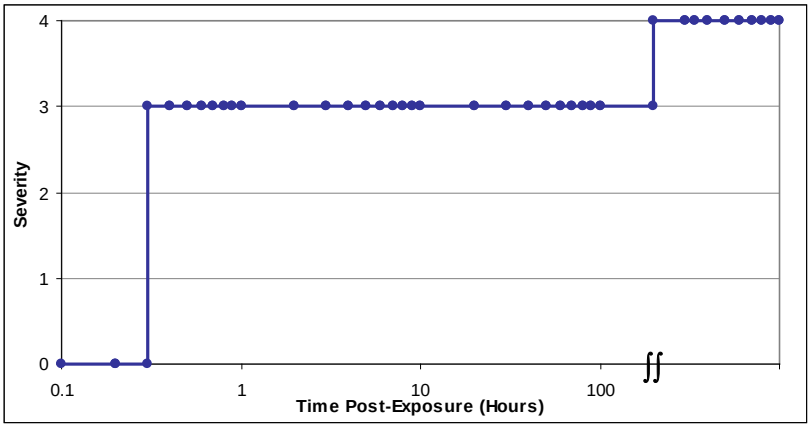


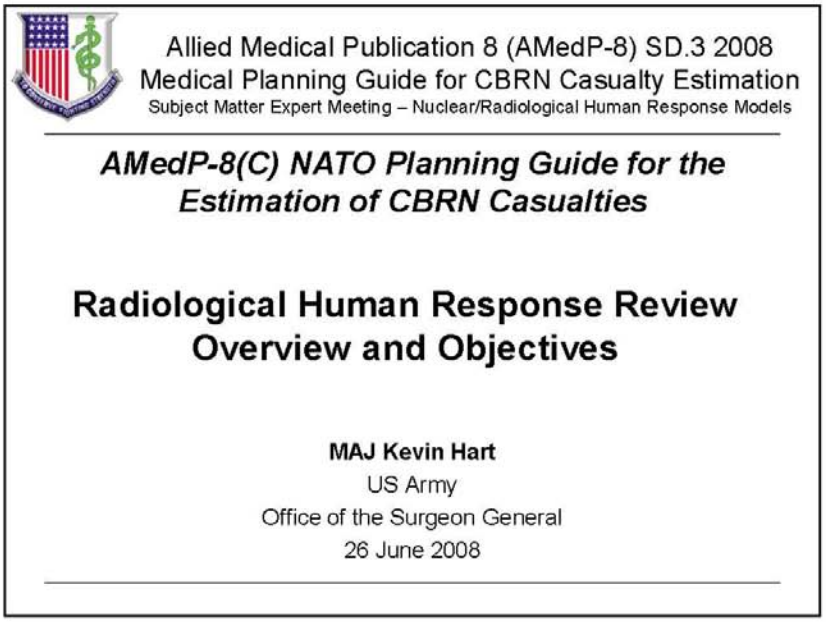

**Figure 8. Irradiation Injury Profile for Dose Range ≥ 8.3 Gy***

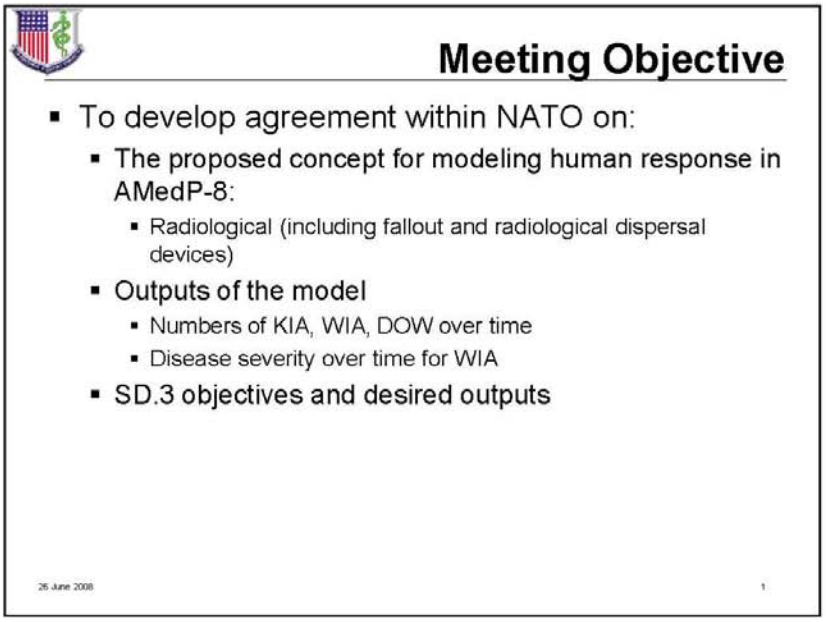
*After approximately 100 hours, the time-component portion of the profiles should be neglected for doses in excess of 5 Gy as indicated by the "SS" marks on the injury profiles. Profiles should be followed up to the calculated time-to-death. KIA or DOW due to whole-body radiation dose should be determined by time-to-death calculations only.

# II. BRIEFINGS

THIS PAGE INTENTIONALLY LEFT BLANK

## A. Radiological Human Response Review Overview and Objectives – *Briefing*



## AMedP-8(C) Purpose

- To provide a methodology for estimating casualties occurring as a consequence of chemical, biological, radiological or nuclear (CBRN) attacks against Allied targets, military or civilian, to support the NATO medical planning process. The methodology is designed to provide estimates of time dependence of the incidence of symptoms by type and severity, numbers of casualties, to include numbers of fatalities.



## AMedP-8 (C) Background

- Part of series of Allied Medical Publications for NBC Planning and Response
  - AMedP-6(C), NATO Handbook on the Medical Aspects of NBC Defensive Operations
    - Treatment and Medical Management at the Physician – Patient level
  - AMedP-7(D), Concept of Operations for Medical Support in NBC Environments
    - Medical Management at the Unit/Operational Level
  - AMedP-8(B), Medical Planning Guide of NBC Battle Casualties
    - Casualty estimation at the Unit/Operational Level

## Draft Development Process

- SD.1 – Outline of proposed document
- SD.2 – Description of methodology up to point of individual estimate of exposure
  - Algorithms and required parameters for components other than human response models
- SD.3 – Complete description of methodology, to include human response to CBRN agents and insults
  - Algorithms and required parameters for human response models
  - Casualty estimation methodology
- Connect to Casualty Estimation Tool
  - Provide input to NATO conventional casualty estimation tools
  - Provide additional capabilities to Nations, as necessary (unsupported)
- Technical Reference
  - Reference documentation available to NATO



## Current Efforts

- STANAG 2476, Ed 2, Addendum to AMedP-8(B)
  - Ratified and promulgated 20 Dec 2007
- Development of Study 2553, Ed 1, AMedP-8(C) SD.3 - NATO Planning Guide For The Estimation Of CBRN Casualties (new version)
  - SD.2 distributed October 2007
  - SD.3 under development

## AMedP-8(C) Study Timeline

- SD.3 (Describe algorithms and required parameters for human response models)
  - Custodial Meetings--review technical aspects of modeling human response with national Subject Matter Experts
    - 21-22 April 2008, Chemical agents (Munich, in conjunction with German Medical Chemical Conference)
    - 8-9 May 2008, Biological agents (San Lorenzo de El Escorial, in conjunction with 21st BioMedAC)
    - **23-26 June 2008, Nuclear effects & Radiological agents (Albuquerque, New Mexico)**
  - September 2008, "Virtual Custodial Meeting" for final pre-coordination review of CBRN casualty estimation (by correspondence)
  - November 2008, Publish SD.3 for review
  - February 2009, Custodial Meeting in conjunction with CBRNMedWG Meeting to adjudicate SD.3 comments and discuss input to NATO conventional casualty estimation tools (Brussels)



## Agenda - Thursday, June 26, 2008

| | |
|---|---|
| 0830 – 0845 | Radiological Objective & Meeting Overview – MAJ Kevin Hart, US Army |
| 0845 – 0915 | General Radiological Human Response Modeling Concepts – Dr. Carl Curling |
| 0915 – 1015 | Radiological Exposure Environments – Dr. Robert Zirkle |
| *1015 – 1045* | *Coffee Break* |
| 1045 – 1115 | Illustrative Example – Radiological – Dr. Robert Zirkle |
| 1115 – 1200 | Radiological Human Response Model – Ms. Deena Disraelly |
| *1200 – 1300* | *Lunch* |
| 1300 – 1345 | Radiological Human Response Model (continued) – Ms. Deena Disraelly |
| 1345 – 1430 | Radiological Casualty Criteria – Dr. Carl Curling |
| 1430 – 1530 | Invited Presentation – COL Dirk Densow, DEU |
| *1530 – 1600* | *Coffee Break* |
| 1600 – 1630 | Review, Conclusions & Way Ahead – MAJ Kevin Hart, US Army |
| *1630* | *Adjourn* |

# Questions?

## Contact

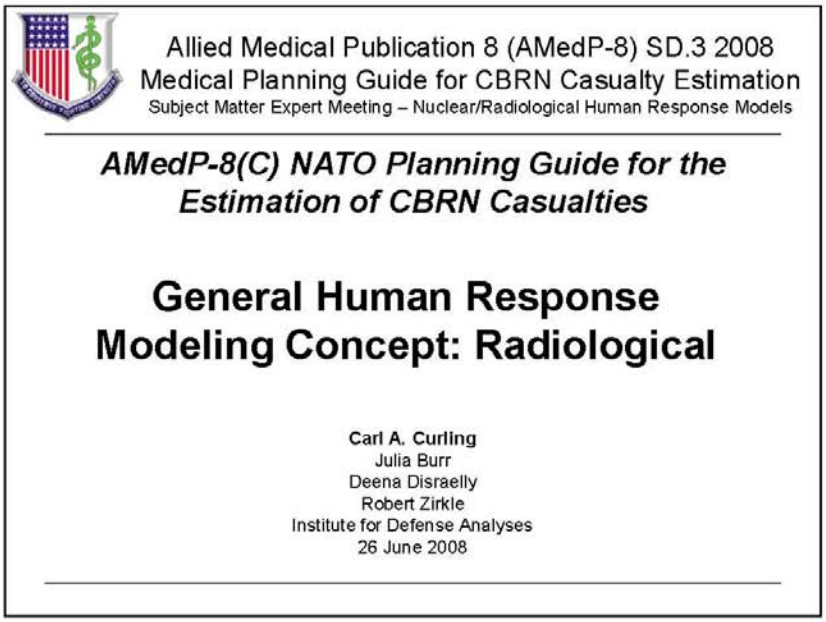
Kevin G. Hart, CHP

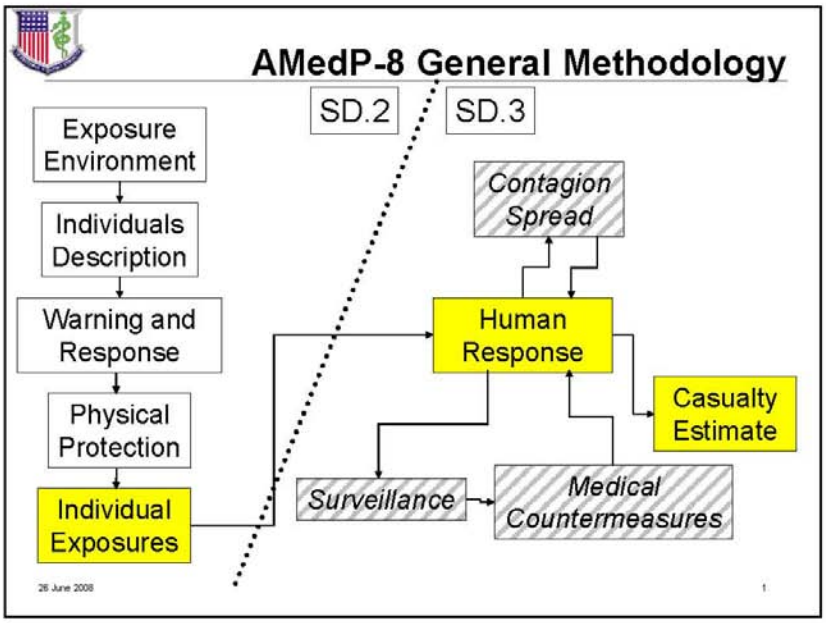
MAJ, MS
CBRN Staff Officer
ATTN: DASG-HCF
5111 Leesburg Pike, Suite 401A
Falls Church, VA 22041-3258
Fax: (703) 681-4971

kevin.hart@us.army.mil
(703) 681-8185

THIS PAGE INTENTIONALLY LEFT BLANK

## B. General Human Response Modeling Concept: Radiological – *Briefing*



## AMedP-8 Human Response Models

- The proposed Human Response Models:
  - Are described by injury profile maps which are based upon injury progression maps, or signs/symptoms severities over time
  - Allow for estimation of:
    - KIA as a function of specific levels of effect
    - WIA at the time at which signs/symptoms and/or injury reach a specified severity level or as a function of specific effect levels
    - DOW at some time after agent or effect exposure as a function of an agent/effect-related estimation or a specified severity level



## AMedP-8 Human Response Models

- Estimates the status over time of personnel exposed to some Chemical, Biological, Radiological, or Nuclear agent or effect
- Estimates the number of people who:
  - May be expected to require medical treatment
  - Are anticipated KIA, WIA, and DOW due to the agent or effect exposure
- Does NOT anticipate the number of people who:
  - May seek medical assistance (battle stress cases)
  - May be injured or killed indirectly (i.e. as a result of car accidents, heart attacks, etc)

## AMedP-8 Working Definitions

- **Human response model** (also known as a casualty estimation model)
  - Usually one component of a larger suite of models
  - Used to estimate status over time of personnel exposed to some event involving CBRN agents
  - The model does not anticipate the number of people who may seek medical assistance or the number who may be injured or killed indirectly (i.e. as a result of car accidents, heart attacks, etc)
- **Casualty**
  - "In relation to personnel, any person who is lost to his organization by reason of having been declared dead, wounded, diseased, detained, captured or missing." (AAP-6)
- **Radiation casualty**
  - "Any person who is lost to his organization by reason of having been declared dead, wounded or diseased as a result of exposure to ionizing radiation." (AMedP-13)



*Definitions from NATO documents: AMedP-8(C), AAP-6, and AMedP-13.*



## AMedP-8 Working Definitions (cont'd)

- **Injury**
  - *"Effects—including disease and wounds—resulting in the damage or deterioration of health"*
    - To encompass the full range of disease, wounds, and other trauma resulting from the nuclear R, B, & T insults, the term "injury" is introduced
    - Injuries may be caused by numerous external insults including chemical, biological, radiological, radiation, blast, and thermal hazards
    - NATO does not specifically define "injury"
      - The *NATO Glossary of NBC Terms and Definitions, English and French, Allied Administrative Publication-21* (AAP-21), defines "Medical Countermeasures (nuclear, chemical, and biological)" in terms of injuries—"those medical interventions designed to diminish the susceptibility of personnel to the lethal and damaging effects of chemical, biological and radiological hazards and to treat any injuries arising from exposure to such hazards."
      - Thus, this definition suggests that all damages to personnel health resulting from CBRN hazards may be classified as "injuries."

## AMedP-8 Working Definitions

- **Killed in Action**
  - "A battle casualty who is killed outright or who dies as a result of wounds or other injuries before reaching a medical treatment facility." (AAP-6)
  - Based on conversations with NATO CBRN Medical Working Group participants, individuals will be assessed as KIA if their injury progression (or other method of calculation) suggests that they would express exposure effects resulting in imminent danger to life for at least 15 minutes before 30 minutes post-exposure
- **Wounded in Action**
  - "A battle casualty other than "killed in action" who has incurred an injury [or disease] due to an external agent or cause. The term encompasses all kinds of wounds and other injuries incurred in action, whether there is a piercing of the body, as in a penetrating or perforated wound, or none, as in the contused wound; all fractures, burns, blast concussions, all effects of biological and chemical." (AAP-6)
- **Died of Wounds**
  - "A battle casualty who dies of wounds [or disease] or other injuries received in action, after having reached a medical treatment facility." (AAP-6)



*Definitions from NATO documents: AMedP-8(C), AAP-6, and AMedP-13.*



## SD.3 Fundamental Concept

- An individual is considered a casualty at the time of first onset of illness/injury-specific signs/symptoms at a specified severity level

*If (Severity at time t ≥ Effects Severity Level)*
*for any subset of symptoms at time t,*
*Then the individual is a casualty (WIA) at time t*

- AMedP-8 specifies the symptoms over time that are used to determine whether an individual is declared dead, wounded, or diseased and thereby considered to be a casualty
- The nature of symptoms and their times of onset depend on the agent

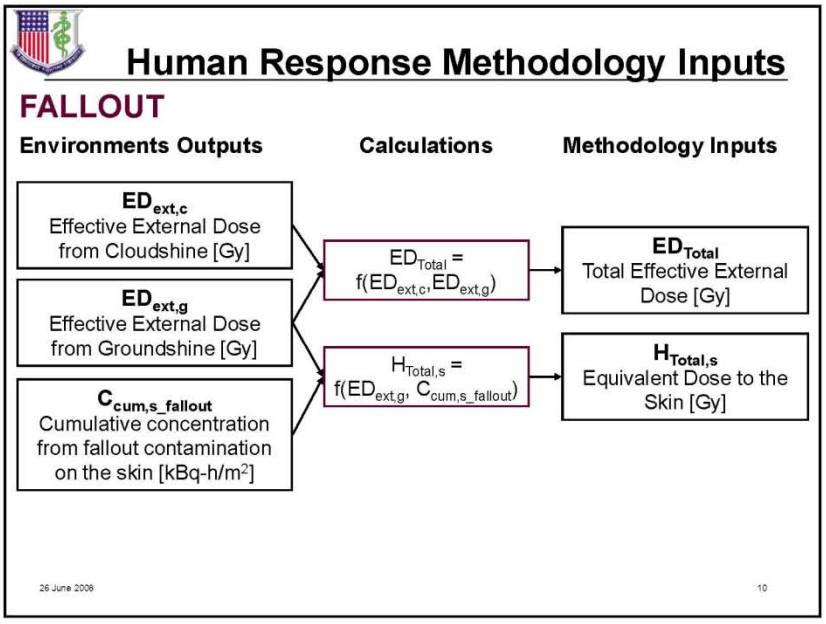
## SD.3 Development Process

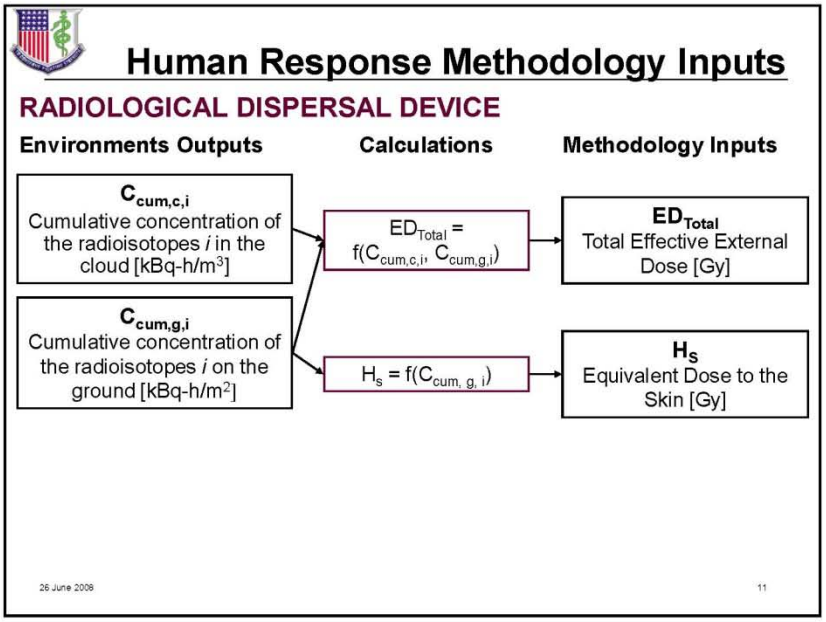
- Step 1: Identification of CBRN agents and effects and applicable routes of exposure
- Step 2: Identification of appropriate systems, signs & symptoms for each agent and effect
- **Step 3: With the assistance of SMEs, achieve consensus on the signs and symptoms maps for each agent and effect**
- Step 4: Determine the applicable estimation values:
  - Effects levels resulting in KIA
  - Signs and symptoms severity associated with WIA
  - Dose/Effects-related algorithms and/or signs and symptoms severities likely to result in DOW



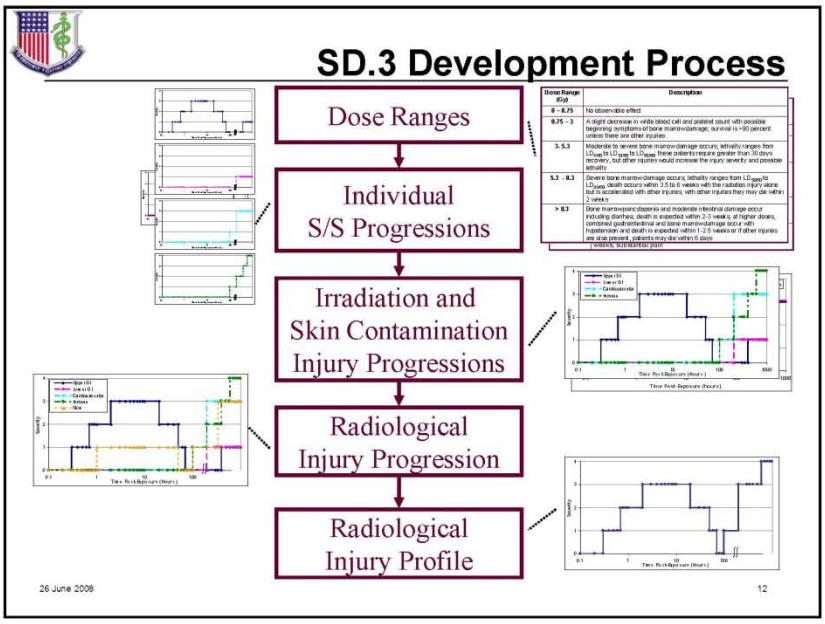
## Radiological Environments

- Fallout
  - Gamma exposure due to air immersion [Gy]
  - Gamma exposure due to ground deposition [Gy]
  - Contamination Dose to the Skin [kBq-h/$m^2$]
    - Assumed equal to the ground deposition
- Radiological dispersal devices
  - Cloud dose (also known as "air immersion") [kBq-h/$m^3$]
  - Ground deposition [kBq-h/$m^2$]


Human Response Methodology Inputs
FALLOUT
Environments Outputs
Calculations
Methodology Inputs
ED ext,c
Effective External Dose from Cloudshine [Gy]
ED ext,g
Effective External Dose from Groundshine [Gy]
C cum,s_fallout
Cumulative concentration from fallout contamination on the skin [kBq-h/m2]
ED Total = f(ED ext,c, ED ext,g)
H Total,s = f(ED ext,g, C cum,s_fallout)
ED Total
Total Effective External Dose [Gy]
H Total,s
Equivalent Dose to the Skin [Gy]
26 June 2008
10


Human Response Methodology Inputs
RADIOLOGICAL DISPERSAL DEVICE
Environments Outputs
Calculations
Methodology Inputs
C cum,c,i
Cumulative concentration of the radioisotopes i in the cloud [kBq-h/m3]
C cum,g,i
Cumulative concentration of the radioisotopes i on the ground [kBq-h/m2]
ED Total = f(C cum,c,i, C cum,g,i)
H s = f(C cum, g, i)
ED Total
Total Effective External Dose [Gy]
H S
Equivalent Dose to the Skin [Gy]
26 June 2008
11

## SD.3 Development Process






## Signs/Symptoms Systems

| | Irradiation | Contamination |
|---|---|---|
| Cardiovascular | X | |
| Immune | X | |
| Lower Gastrointestinal | X | |
| Skin (Radiological) | | X |
| Upper Gastrointestinal | X | |

## Severity Definitions

- No Observable Effect ≈ Severity = 0
- Mild ≈ Severity = 1
- Moderate ≈ Severity = 2
- Severe ≈ Severity = 3
- Very Severe ≈ Severity = 4



## Severity Definitions

| | Degrees | Description |
|---|---|---|
| 0 | N.O.E. | No observable effect |
| 1 | Mild | Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms |
| 2 | Moderate | Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission |
| 3 | Severe | Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms |
| 4 | Very Severe | Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms |

## Overarching Model Assumptions

- Human response can be modeled over time as a function of dose-related signs and symptoms
  - Dose-related signs and symptoms apply for all doses/insults in a specified dose/insult range
- Human response to an exposure can be represented by the median individual in each dose/insult band
- Prior to exposure, individuals are in perfect health
- 70 kilogram man, breathing 15 liters per minute (moderate exertion)
- Human response is modeled as primary response to prompt, instantaneous insults
  - Human response does not include secondary, higher order, or indirect effects except as specifically noted
  - Human response for the entire exposed population begins simultaneously immediately following the radiological event



## Overarching Model Assumptions (cont'd)

- Severity of signs and symptoms resulting from combined insults is interactive
- While other signs and symptoms occur, the signs and symptoms manifested in the represented physiological systems are those systems most likely to cause an exposed individual to seek medical attention and thereby become a loss to the organization
- Dose fractionation or protraction is not considered
- Internal contamination (due to inhalation, ingestion or injection) is negligible
- Skin contamination dose is due to beta particles only
- Activity deposited on the skin is equal to the activity deposited on the ground

*Route of exposure assumptions will be addressed in a separate briefing*

## Model Limitations

- The model cannot address several types of casualties
  - The model does not address battle stress cases
  - Secondary, higher order, and indirect casualties and secondary infections/diseases are not modeled
- Dose fractionation or protraction is not considered in the estimation of radiological dose
- Medical countermeasures and medical treatments are not addressed – all injury progressions assume no medical intervention
- The model does not attempt to account for recovery



## Model Strengths & Weaknesses

- Model represents both the personnel status and injury progression and flow over time
  - Planners can select and collate data as desired
- Model allows the user to determine the severity level at which effects are expected to cause WIA
- Model is deterministic and based on the median individual
  - It does not allow for variations of dose-response as might be expected in an actual population
- Much of the model is based on data which is ten or more years old
  - Additional review with SMEs may be required to determine if more recent research would change proposed injury progressions

# Questions?

## Contact

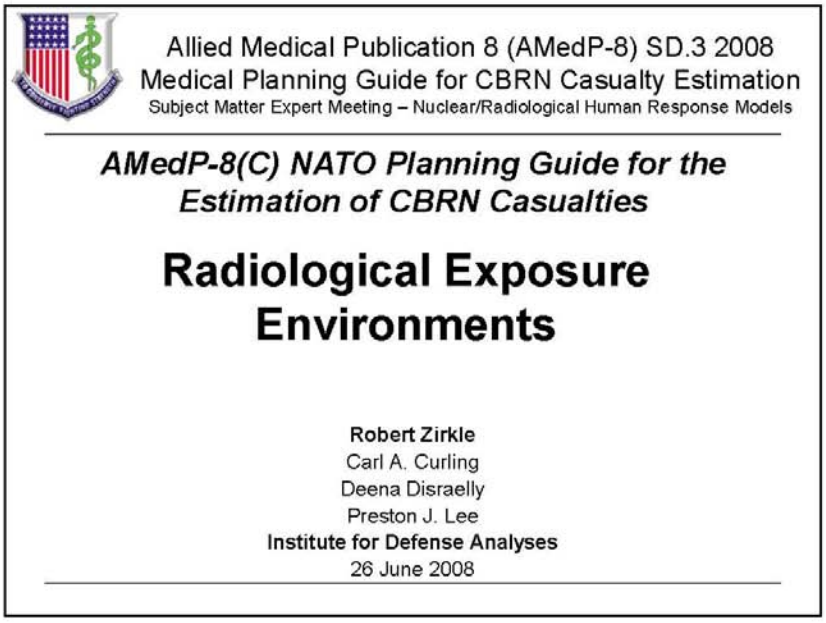
Carl Curling, Sc.D. Deena Disraelly Robert Zirkle, PhD

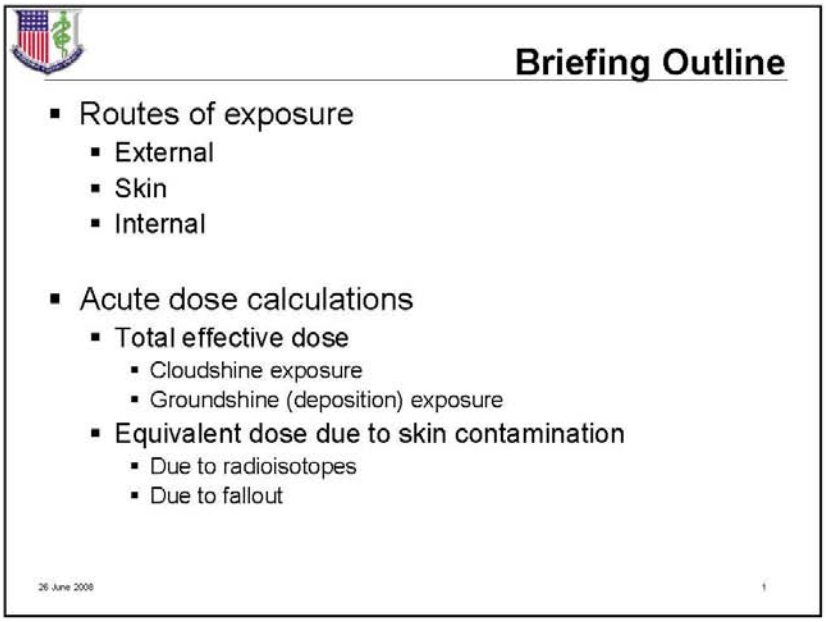
Strategy, Forces & Resources Division
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
FAX – 703-845-2255

ccurling@ida.org 703-578-2814
ddisrael@ida.org 703-845-6685
rzirkle@ida.org 703-845-2038

THIS PAGE INTENTIONALLY LEFT BLANK

## C. Radiological Exposure Environments – *Briefing*



# ROUTES OF EXPOSURE



## Radiological Route of Exposure Assumptions

- External dose – Gamma exposure
  - Cloudshine (or air immersion)
  - Groundshine (or deposition)
- Skin contamination – Beta exposure
  - Due to radioisotopes
    - Beta exposure to the skin while skin is contaminated
      - Beta on skin contributes to skin dose only
    - Only hands and face are uncovered and thereby affected
    - Contribution from deposition on clothing is neglected
  - Due to fallout
    - Only hands and face are uncovered and thereby affected
    - Contribution from deposition on clothing is neglected
- Exposed individuals enter the fallout area after the fallout cloud has passed (fallout cloudshine exposure is negligible)

## Radiological Route of Exposure Assumptions (cont'd)

- Internal contamination is considered negligible
  - Dose coefficients for inhalation are typically in the $10^{-9}$ to $10^{-12}$ Gy/Bq range (3 orders of magnitude smaller than those for external dose or skin contamination)
  - Vast quantities of radioactive material would have to be inhaled (and/or ingested) in order to produce acute effects in the time period of interest
  - Realistic scenarios may not be likely to lead to acute doses from inhalation



## DOSE CALCULATIONS

## Dose Contributors

| Radiation type → | Gamma | Beta | Alpha |
|---|---|---|---|
| External | YES | YES | NO |
| Contamination | NO | YES | NO |



## Radiological Environments

- Fallout
  - Gamma exposure due to air immersion [Gy]
  - Gamma exposure due to ground deposition [Gy]
  - Contamination Dose to the Skin [kBq-h/$m^2$]
    - Assumed equal to the ground deposition
- Radiological dispersal devices
  - Cloud dose (also known as "air immersion") [kBq-h/$m^3$]
  - Ground deposition [kBq-h/$m^2$]

## Dose Estimation

$$ED_{Total} = ED_{ext} + ED_{inh} + ED_{ing}$$

Simplifies to:

$$ED_{Total} = ED_{ext} = ED_{ext,c} + ED_{ext,g}$$

- $ED_{Total}$ = Total effective dose
- $ED_{ext}$ = Effective dose from external radiation
- $ED_{inh}$ = Total committed effective dose due from inhalation
- $ED_{ing}$ = Total committed effective dose due from ingestion
- $ED_{ext,c}$ = Effective dose from the external cloudshine
- $ED_{ext,g}$ = Effective dose from the external groundshine



## Half-Lives for Selected Radioisotopes

| Isotope | Half-Life |
|---|---|
| $^{60}Co$ | 5.3 years |
| $^{90}Sr$ | 29 years |
| $^{137}Cs$ | 30 years |
| $^{192}Ir$ | 74 days |
| $^{238}Pu$ | 88 years |
| $^{241}Am$ | 433 years |

Sources: Harper, F. T., S. V. Musolino, and W. B. Wente. 2007. Realistic Radiological Dispersal Device Hazard Boundaries and Ramifications for Early Consequence Management Decisions. *Health Physics*, Vol. 93, No. 1. July 2007. p. 1-16; and, IAEA. *Generic Procedures for Assessment and Response During a Radiological Emergency*, IAEA-TECDOC-1162, 2000

## External Cloudshine Dose

$$ED_{ext,c} = \sum_{i=1}^{n} (C_{cum,c,i} \cdot CF_{c,i})$$

- $ED_{ext,c}$ = Effective dose from the external cloud exposure in Gy (due to gamma only)
- n = Number of radioisotopes
- $C_{cum,c,i}$ = Cumulative concentration of the radioisotopes *i* in the cloud in kBq-hours/$m^3$
- $CF_{c,i}$ = Dose conversion factor for cloudshine in (Gy/hours)/(kBq/$m^3$) for radioisotope *i*

- $CF_{c,i}$ converts the average activity concentration due to radioisotope *i* to an effective dose



## Selected CF's for External Cloudshine

| Isotope | Dose conversion factor (Gy/h)/(kBq/$m^3$) |
|---|---|
| $^{60}Co$ | $5.6 \times 10^{-7}$ |
| $^{90}Sr$ | $0 \times 10^{0}$ |
| $^{137}Cs$ | $1.3 \times 10^{-7}$ |
| $^{192}Ir$ | $1.7 \times 10^{-7}$ |
| $^{238}Pu$ | $1.9 \times 10^{-11}$ |
| $^{241}Am$ | $4.1 \times 10^{-9}$ |

Source: IAEA, *Generic Procedures for Assessment and Response During a Radiological Emergency*, IAEA-TECDOC-1162, 2000

## External Groundshine Dose

$$ED_{ext,g} = \sum_{i=1}^{n} (C_{cum,g,i} \cdot CF_{g,i})$$

- $ED_{ext,g}$ = Effective dose from ground deposition in Gy (due to gamma only)
- n = Number of radioisotopes
- $C_{cum,g,i}$ = Cumulative concentration of the radioisotope *i* on the ground in kBq-hours/m$^2$
- $CF_{g,i}$ = Ground dose conversion factor for ambient dose rate expressed in (Gy/hours)/(kBq/m$^2$) for radioisotope *i*

- $CF_{g,i}$ converts the average deposition due to radioisotope *i* to an effective dose



## Selected CF's for External Groundshine

| Isotope | Dose conversion factor (Gy/h)/(kBq/m$^3$) |
|---|---|
| $^{60}$Co | 8.3 x 10$^{-9}$ |
| $^{90}$Sr | 1 x 10$^{-12}$ |
| $^{137}$Cs | 2.1 x 10$^{-9}$ |
| $^{192}$Ir | 2.8 x 10$^{-9}$ |
| $^{238}$Pu | 3.0 x 10$^{-12}$ |
| $^{241}$Am | 9.7 x 10$^{-11}$ |

Source: IAEA. *Generic Procedures for Assessment and Response During a Radiological Emergency*, IAEA-TECDOC-1162, 2000

## Equivalent Dose to Skin from Skin Contamination

$$H_s = \sum_{i=1}^{n} (C_{cum,s,i} \cdot CF_{s,i})$$

- $H_s$ = Equivalent dose to the skin in Gy (due to beta only)
- n = Number of radioisotopes
- $C_{cum,s,i}$ = Cumulative concentration of the radioisotope *i* on the skin in kBq-hours/$m^2$
- $CF_{s,i}$ = Dose conversion factor in (Gy/hours)/(kBq/$m^2$)
- $CF_{s,i}$ converts the average activity contamination on skin due to radioisotope *i* to an equivalent dose



## Selected CF's for Skin Contamination

| Isotope | Dose conversion factor (Gy/h)/(kBq/$m^2$) |
|---|---|
| $^{60}Co$ | $7.8 \times 10^{-8}$ |
| $^{90}Sr$ | $3.5 \times 10^{-7}$ |
| $^{137}Cs$ | $1.6 \times 10^{-7}$ |
| $^{192}Ir$ | $1.9 \times 10^{-7}$ |
| $^{238}Pu$ | $3.7 \times 10^{-10}$ |
| $^{241}Am$ | $1.9 \times 10^{-9}$ |

Source: IAEA, *Generic Procedures for Assessment and Response During a Radiological Emergency*, IAEA-TECDOC-1162, 2000

## Equivalent Dose to Skin from Fallout Skin Contamination

$$H_s = C_{cum,s\_fallout} \cdot CF_{s\_fallout}$$

- $H_s$ = Equivalent dose to the skin in Gy (due to beta only)
- $C_{cum,s\_fallout}$ = Cumulative concentration from fallout contamination on the skin in kBq-hours/m$^2$
- $CF_{s\_fallout}$ = Dose conversion factor for fallout contamination in (Gy/hours)/(kBq/m$^2$)
- $CF_{s\_fallout}$ converts the average activity contamination on skin due to fallout deposition to an equivalent dose



## CF for Fallout Contamination

| Time After Detonation | Epidermal Thickness: 4.00 mg/cm$^2$ (Gy/h)/(kBq/m$^2$) |
|---|---|
| 1 h | 2.66 X 10$^{-7}$ |
| 2 h | 2.65 X 10$^{-7}$ |
| 4 h | 2.64 X 10$^{-7}$ |
| 6 h | 2.64 X 10$^{-7}$ |
| 12 h | 2.63 X 10$^{-7}$ |
| 1 d | 2.60 X 10$^{-7}$ |
| 2 d | 2.55 X 10$^{-7}$ |
| 3 d | 2.53 X 10$^{-7}$ |
| 1 w | 2.49 X 10$^{-7}$ |
| 2 w | 2.49 X 10$^{-7}$ |
| 1 mo | 2.50 X 10$^{-7}$ |
| 2 mo | 2.48 X 10$^{-7}$ |
| 4 mo | 2.47 X 10$^{-7}$ |
| 6 mo | 2.47 X 10$^{-7}$ |
| 9 mo | 2.48 X 10$^{-7}$ |

Source: DTRA. *NTPR Standard Operating Procedure Stand Method ED04. Forthcoming* (DRAFT)

## Equivalent Dose to Skin from Fallout Ground Deposition

$$H_{fallout,s} = (ED_{fallout\_Total} \cdot (DR_{\beta/\gamma\_hands} + DR_{\beta/\gamma\_head})$$

- $H_{fallout,s}$ = Equivalent dose from fallout to the skin in Gy (due to beta only)
- $ED_{fallout\_Total}$ = Effective whole body gamma dose due to external irradiation
- $DR_{\beta/\gamma\_hands}$ = Beta-to-gamma dose ratio for bare skin at the approximate height of the hands above the ground (100 cm)
- $DR_{\beta/\gamma\_head}$ = Beta-to-gamma dose ratio for bare skin at the approximate height of the head above the ground (160 cm)



## Beta-to-Gamma Dose Ratios – Bare Skin

| Time After Detonation | 100 cm Above Ground | 160 cm Above Ground |
|---|---|---|
| 0.5 h | 10.8 | 7.6 |
| 1 h | 9.4 | 6.4 |
| 2 h | 8.9 | 6.1 |
| 4 h | 10.9 | 7.3 |
| 6 h | 13.4 | 9.0 |
| 12 h | 15.9 | 10.2 |
| 1 d | 13.0 | 7.7 |
| 2 d | 10.1 | 5.4 |
| 3 d | 8.4 | 4.2 |
| 1 w | 6.4 | 3.1 |
| 2 w | 6.8 | 3.3 |
| 1 mo | 8.3 | 4.3 |
| 2 mo | 10.2 | 5.9 |
| 4 mo | 11.1 | 7.1 |
| 6 mo | 12.5 | 8.5 |
| 9 mo | 17.8 | 12.8 |

Source: N.M. Barss and R.L. Weitz, "Reconstruction of External Dose for Beta Radiation Sources of Nuclear Weapon Origin," *Health Physics*, Vol. 91, No. 4 (October 2006), p. 385

## Total Equivalent Dose to Skin from Fallout

$$H_{Total,s} = H_s + H_{fallout,s}$$

- $H_{Total,s}$ = Total equivalent dose to the skin in Gy (due to beta only)
- $H_s$ = Equivalent dose to the skin in Gy (due to beta only)
- $H_{fallout,s}$ = Equivalent dose from fallout to the skin in Gy (due to beta only)



## Outputs

- Total effective dose
  - Utilizes same human response model as is used for nuclear irradiation
- Equivalent dose to the skin
  - Utilizes the signs/symptoms for skin contamination

# Questions?

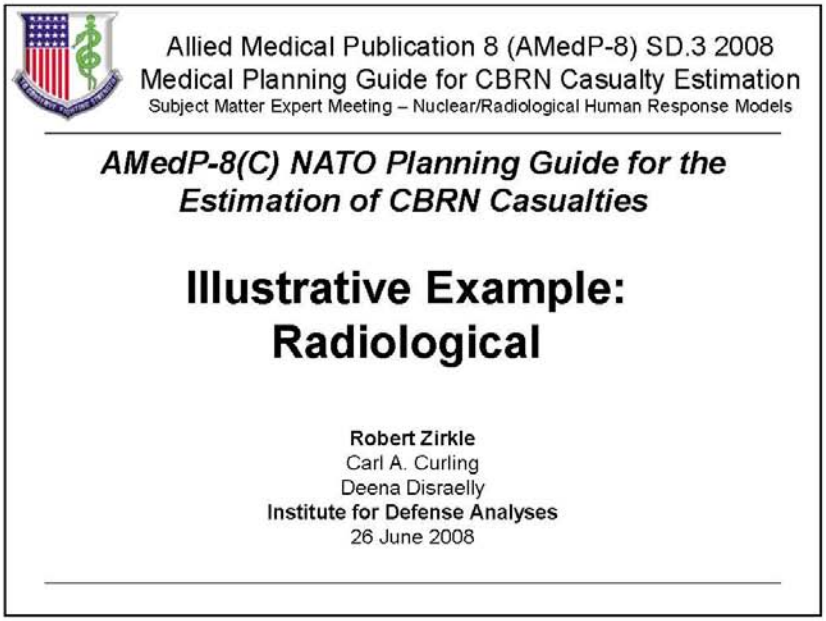
## Contact

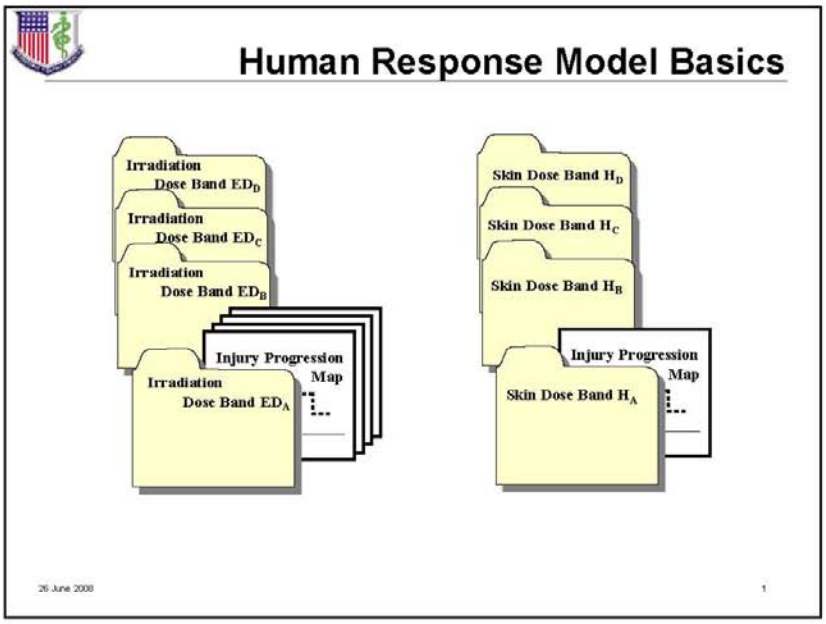
Carl Curling, Sc.D. Deena Disraelly Robert Zirkle, PhD

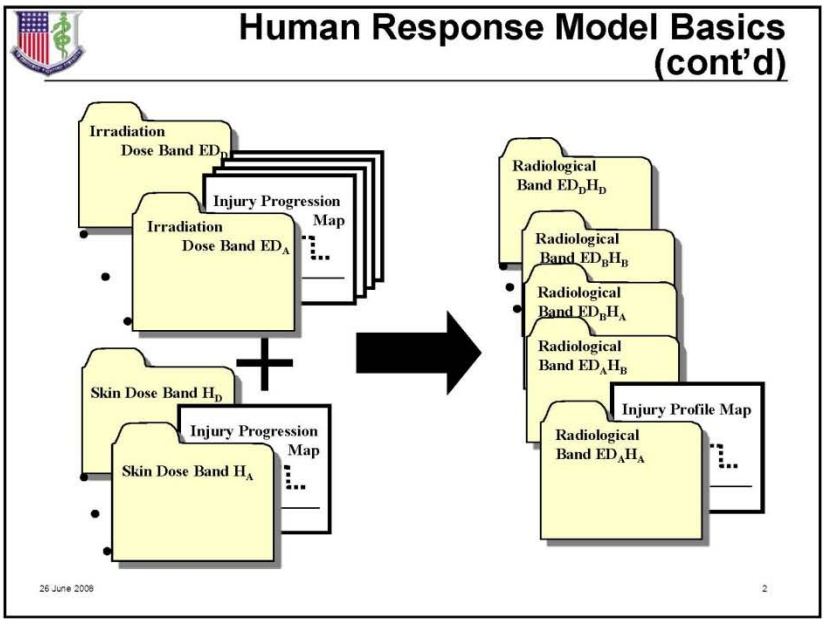
Strategy, Forces & Resources Division
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
FAX – 703-845-2255

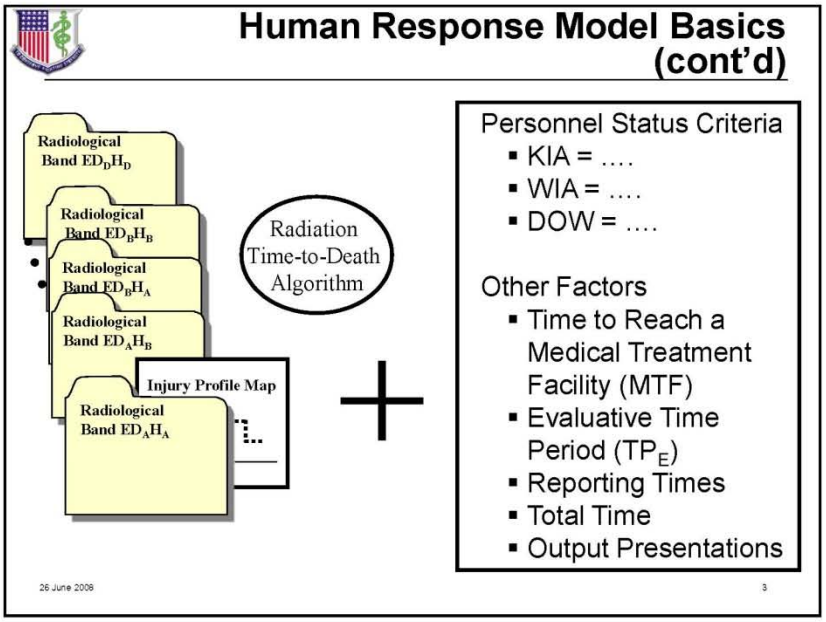
ccurling@ida.org 703-578-2814
ddisrael@ida.org 703-845-6685
rzirkle@ida.org 703-845-2038

## D. Illustrative Example: Radiological – *Briefing*

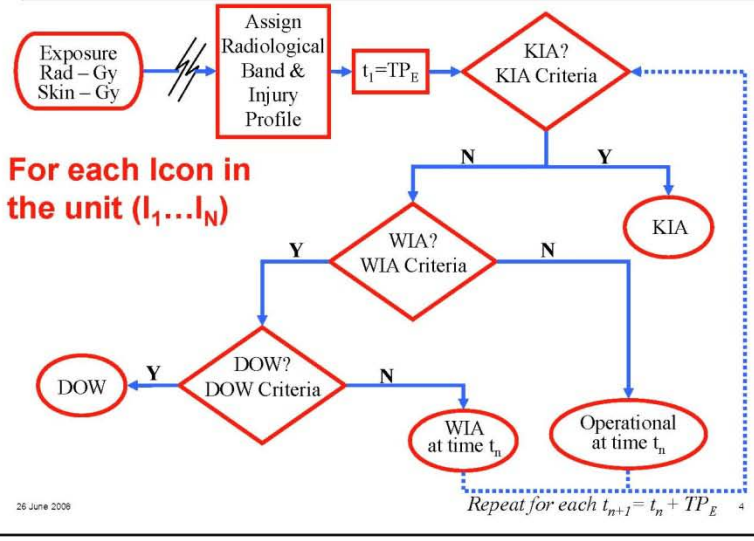



Human Response Model Basics (cont'd)
Irradiation Dose Band $ED_D$
Injury Progression Map
Irradiation Dose Band $ED_A$
Skin Dose Band $H_D$
Injury Progression Map
Skin Dose Band $H_A$
Radiological Band $ED_DH_D$
Radiological Band $ED_BH_B$
Radiological Band $ED_BH_A$
Radiological Band $ED_AH_B$
Injury Profile Map
Radiological Band $ED_AH_A$
26 June 2008
2


Human Response Model Basics (cont'd)
Radiological Band $ED_DH_D$
Radiological Band $ED_BH_B$
Radiological Band $ED_BH_A$
Radiological Band $ED_AH_B$
Injury Profile Map
Radiological Band $ED_AH_A$
Radiation Time-to-Death Algorithm
Personnel Status Criteria
KIA = ….
WIA = ….
DOW = ….
Other Factors
Time to Reach a Medical Treatment Facility (MTF)
Evaluative Time Period ($TP_E$)
Reporting Times
Total Time
Output Presentations
26 June 2008
3

## Estimating Casualties





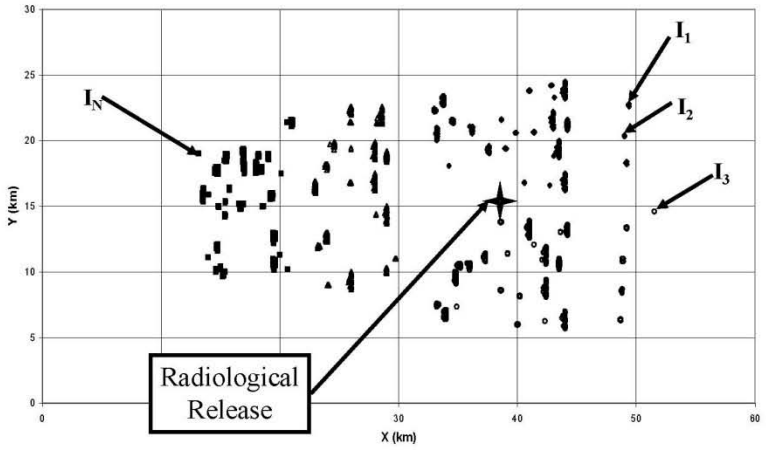

## STEPPING THROUGH A "GAME"

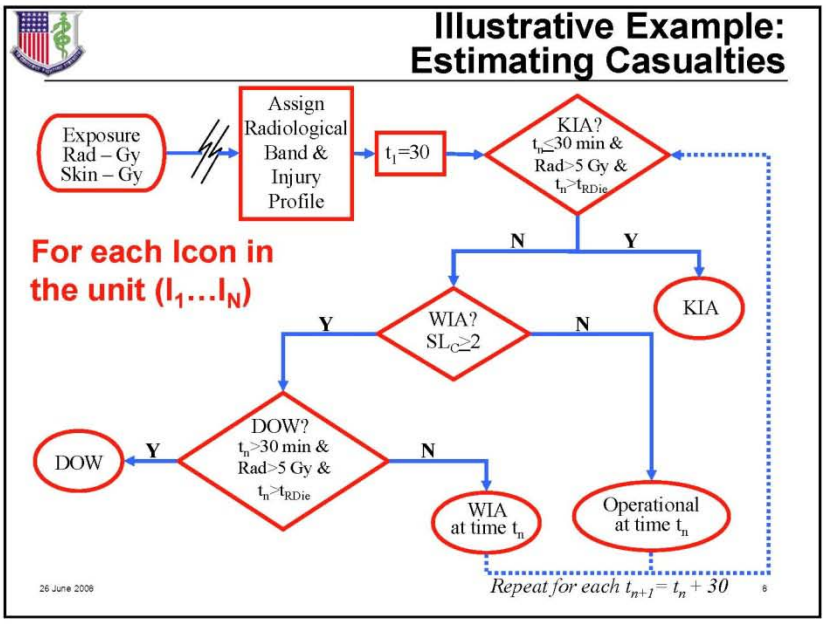
## Illustrative Example: User Defined Parameters

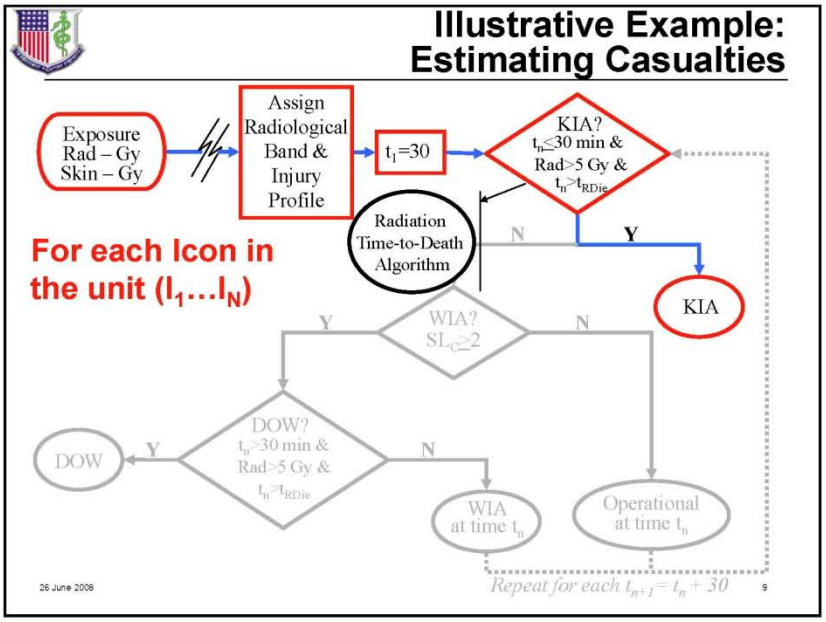
- Time to Reach an MTF = **30 minutes**
- Evaluative Time Period ($TP_E$) = **30 minutes**
- KIA = Satisfy radiation criteria for death within first **30 minutes** of the "game"
- WIA = $SL_C$ at **2 or greater**
- DOW = Satisfy the radiation criteria for DOW after first **30 minutes** of the "game"
- Reporting Times = **1st hour, 1st day, 2nd day….**
- Total Time = **30 days**

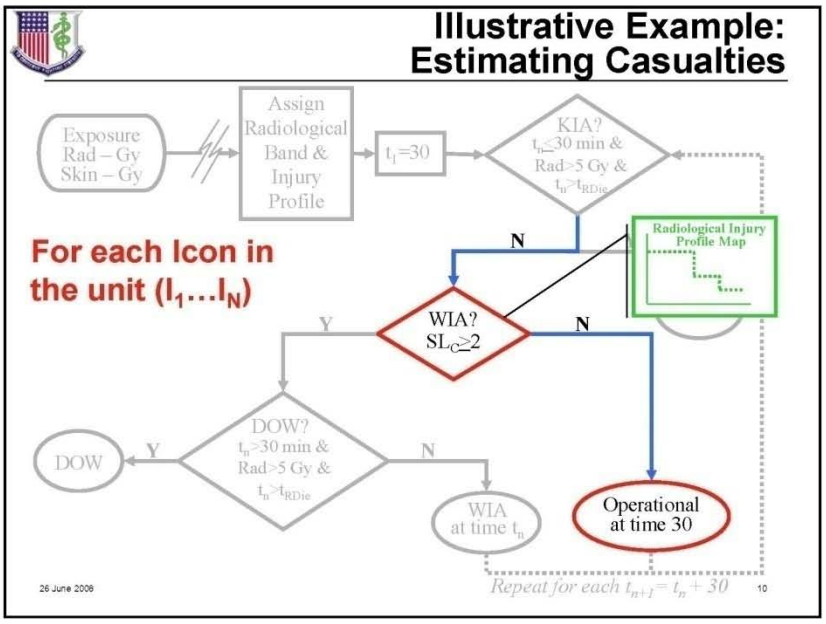


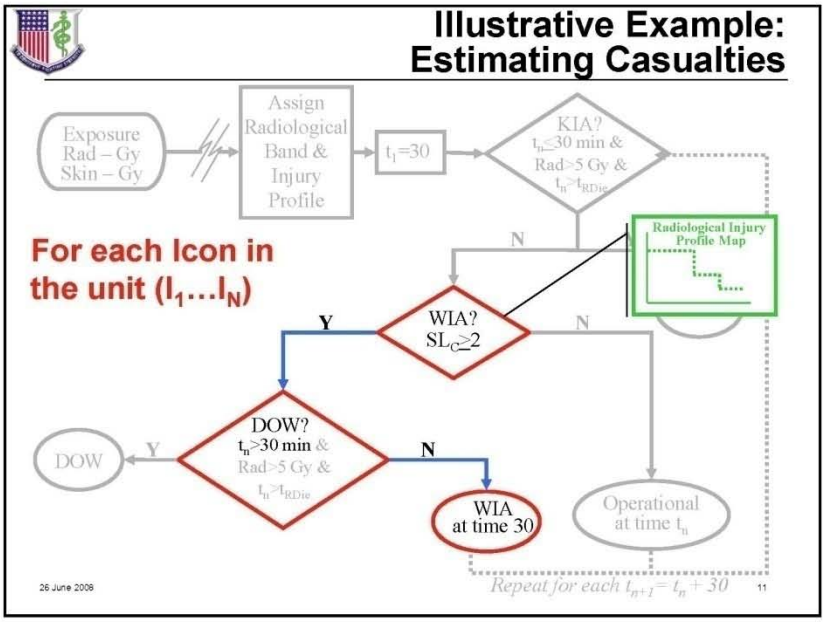
## Illustrative Example: Unit Laydown and Attack

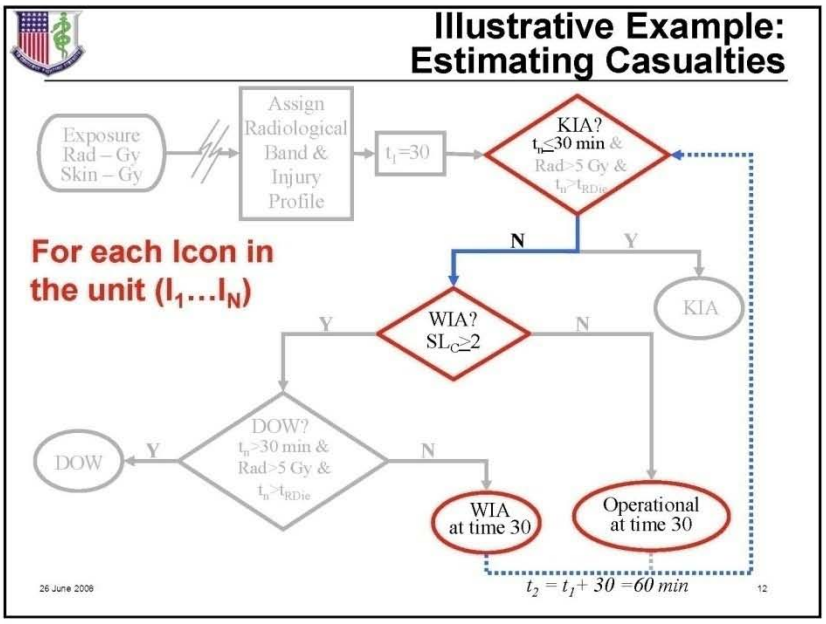


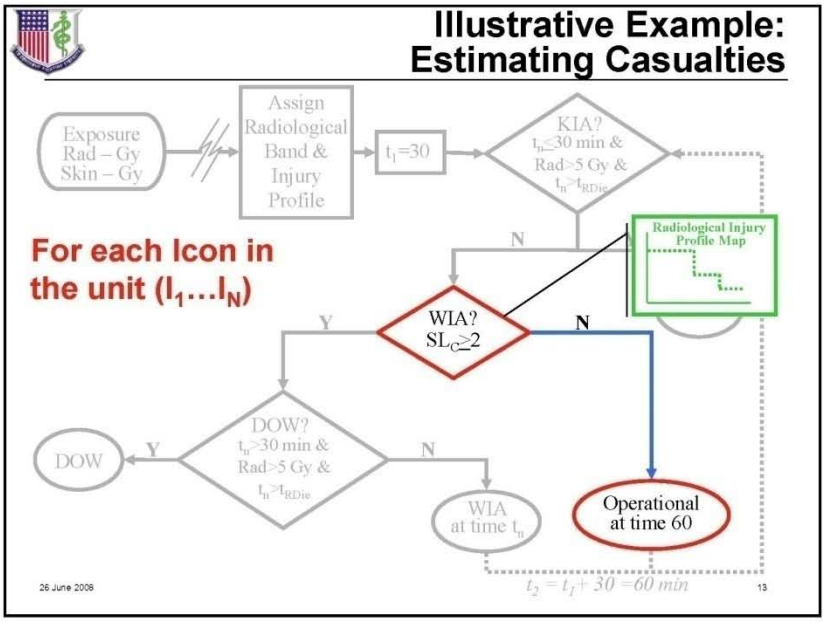

Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Y
For each Icon in
the unit ($I_1 \ldots I_N$)
KIA
WIA?
$SL_C \geq 2$
Y
N
DOW?
$t_n > 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time $t_n$
Operational
at time $t_n$
26 June 2008
Repeat for each $t_{n+1} = t_n + 30$
6

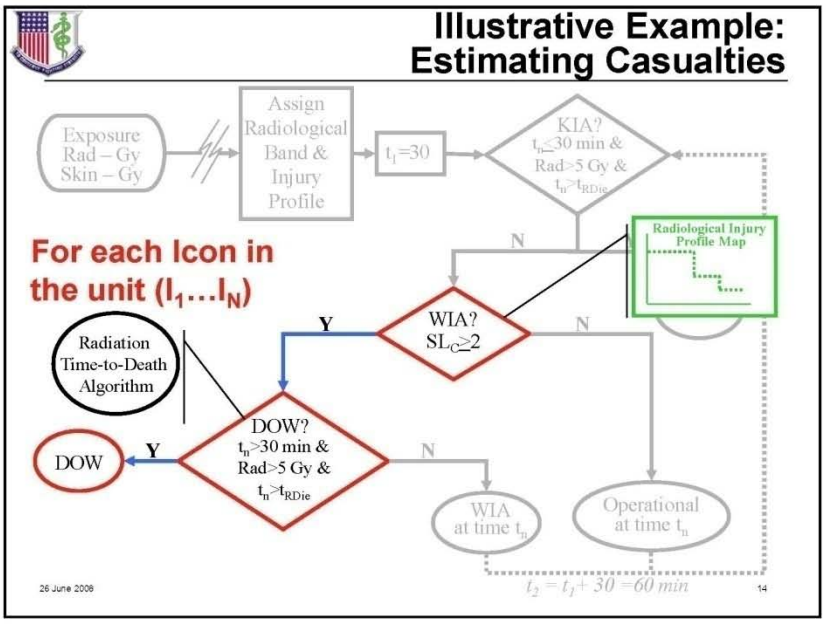

Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
Radiation
Time-to-Death
Algorithm
N
Y
For each Icon in
the unit ($I_1 \ldots I_N$)
KIA
WIA?
$SL_C \geq 2$
Y
N
DOW?
$t_n > 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time $t_n$
Operational
at time $t_n$
26 June 2008
Repeat for each $t_{n+1} = t_n + 30$
9

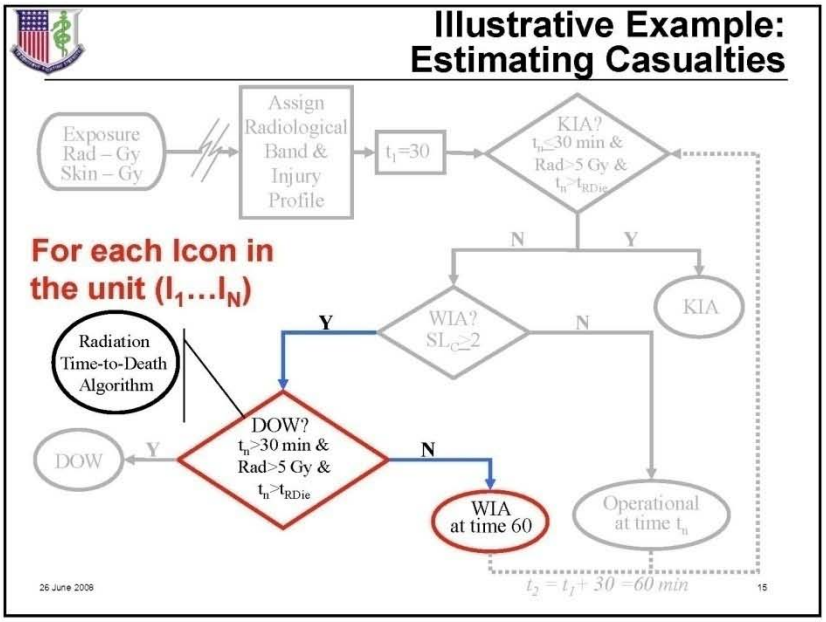

Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Radiological Injury
Profile Map
For each Icon in
the unit ($I_1 \ldots I_N$)
Y
WIA?
$SL_C \geq 2$
N
DOW?
$t_n > 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
Y
DOW
N
WIA
at time $t_n$
Operational
at time 30
26 June 2008
Repeat for each $t_{n+1} = t_n + 30$
10

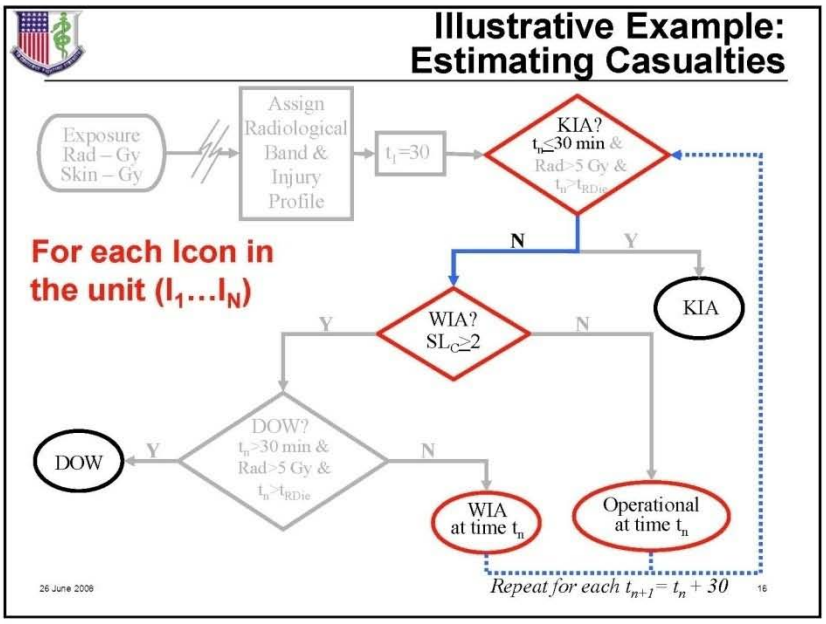

Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Radiological Injury
Profile Map
For each Icon in
the unit ($I_1 \ldots I_N$)
Y
WIA?
$SL_C \geq 2$
N
DOW?
$t_n > 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
Y
DOW
N
WIA
at time 30
Operational
at time $t_n$
26 June 2008
Repeat for each $t_{n+1} = t_n + 30$
11

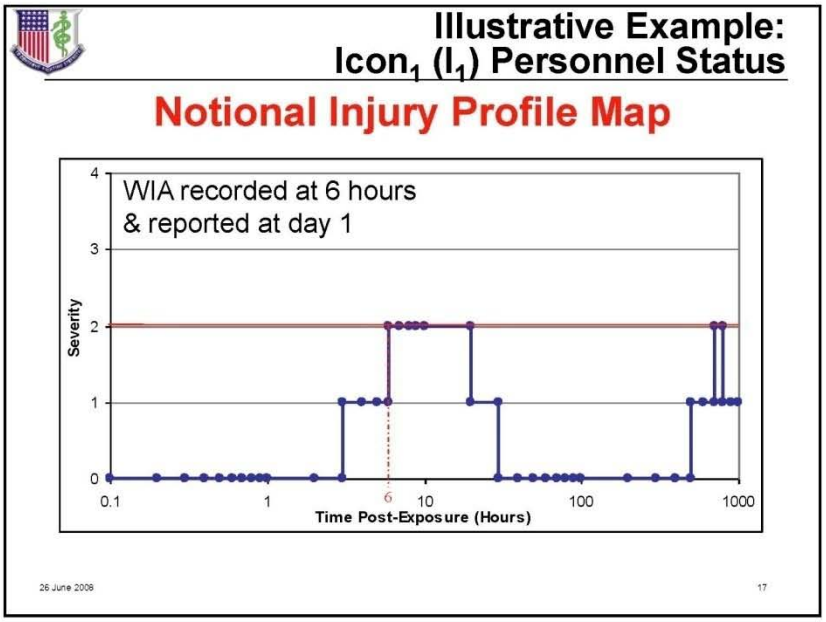

Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Y
For each Icon in
the unit ($I_1 \ldots I_N$)
KIA
WIA?
$SL_C \geq 2$
Y
N
DOW?
$t_n$>30 min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time 30
Operational
at time 30
26 June 2008
$t_2 = t_1 + 30 = 60$ min
12


Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
Radiological Injury
Profile Map
N
For each Icon in
the unit ($I_1 \ldots I_N$)
Y
WIA?
$SL_C \geq 2$
N
DOW?
$t_n$>30 min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time $t_n$
Operational
at time 60
26 June 2008
$t_2 = t_1 + 30 = 60$ min
13


Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Radiological Injury
Profile Map
For each Icon in
the unit ($I_1 \ldots I_N$)
Y
WIA?
$SL_C \geq 2$
N
Radiation
Time-to-Death
Algorithm
DOW?
$t_n$>30 min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time $t_n$
Operational
at time $t_n$
26 June 2008
$t_2 = t_1 + 30 = 60$ min
14


Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Y
KIA
For each Icon in
the unit ($I_1 \ldots I_N$)
Y
WIA?
$SL_C \geq 2$
N
Radiation
Time-to-Death
Algorithm
DOW?
$t_n$>30 min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time 60
Operational
at time $t_n$
26 June 2008
$t_2 = t_1 + 30 = 60$ min
15


Illustrative Example:
Estimating Casualties
Exposure
Rad – Gy
Skin – Gy
Assign
Radiological
Band &
Injury
Profile
$t_1$=30
KIA?
$t_n \leq 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
N
Y
For each Icon in
the unit ($I_1 \ldots I_N$)
KIA
WIA?
$SL_C \geq 2$
Y
N
DOW?
$t_n > 30$ min &
Rad>5 Gy &
$t_n > t_{RDie}$
DOW
Y
N
WIA
at time $t_n$
Operational
at time $t_n$
Repeat for each $t_{n+1} = t_n + 30$
26 June 2008
16


Illustrative Example:
Icon$_1$ ($I_1$) Personnel Status
Notional Injury Profile Map
WIA recorded at 6 hours
& reported at day 1
Severity
0
1
2
3
4
0.1
1
6
10
100
1000
Time Post-Exposure (Hours)
26 June 2008
17

## Illustrative Example: Results

During the course of the "game" the model saved the following data:

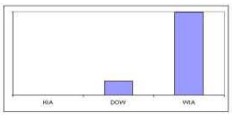
- KIA at the recorded time
- WIA at the recorded time
- DOW at the recorded time



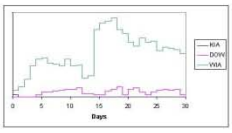
## Illustrative Example: Results

Examples of Output Presentations:

- Personnel Status Totals:




- Personnel Status Differentials:




*These graphs are notional only*

# Questions?

## Contact

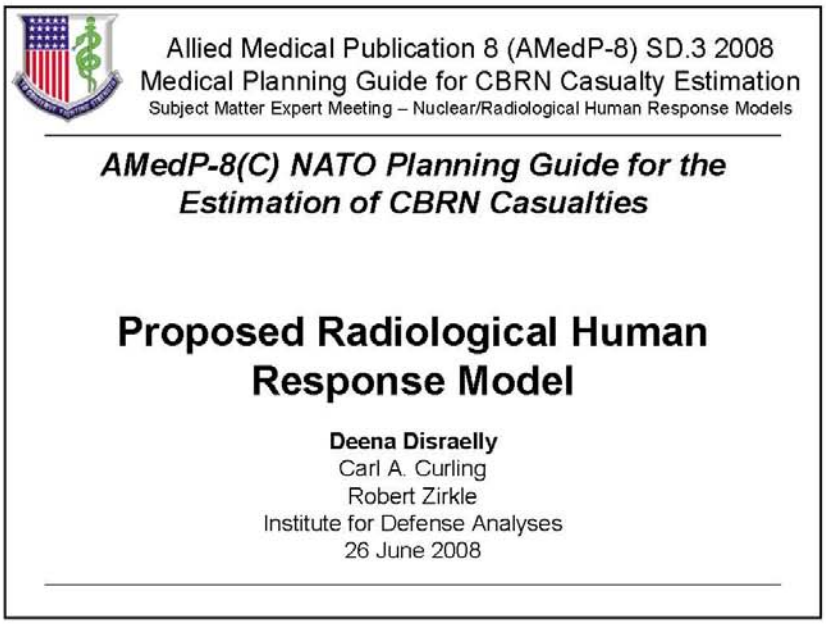
Carl Curling, Sc.D. Robert Zirkle, PhD Deena Disraelly

Strategy, Forces & Resources Division
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
FAX – 703-845-2255

ccurling@ida.org 703-578-2814
rzirkle@ida.org 703-845-2038
ddisrael@ida.org 703-845-6685

THIS PAGE INTENTIONALLY LEFT BLANK

## E. Proposed Radiological Human Response Model – *Briefing*

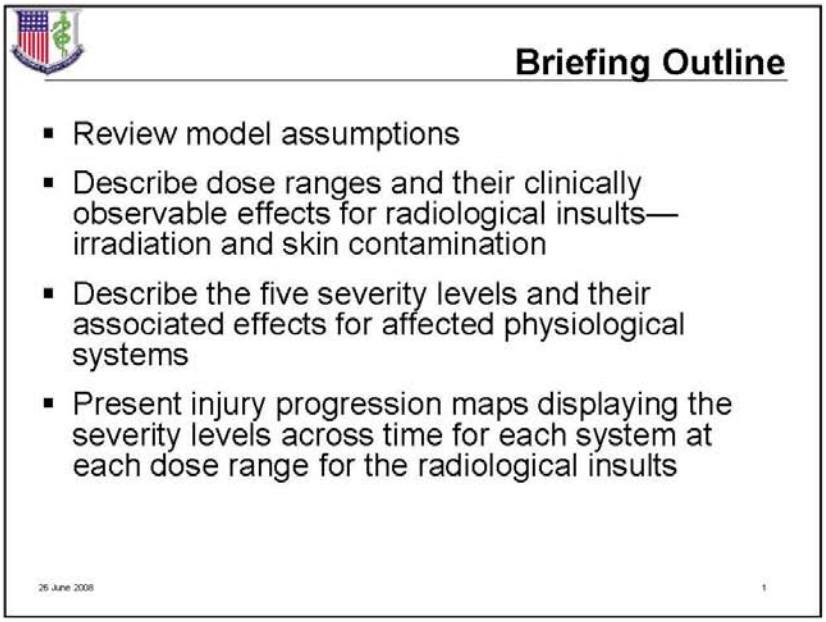


Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

*AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties*

**Proposed Radiological Human Response Model**

**Deena Disraelly**
Carl A. Curling
Robert Zirkle
Institute for Defense Analyses
26 June 2008



**Briefing Outline**

- Review model assumptions
- Describe dose ranges and their clinically observable effects for radiological insults—irradiation and skin contamination
- Describe the five severity levels and their associated effects for affected physiological systems
- Present injury progression maps displaying the severity levels across time for each system at each dose range for the radiological insults

26 June 2008 1

## Human Response Inputs

- Whole body effective dose from external gamma radiation (total effective dose)
  - Human response methodology detailed for nuclear irradiation is used to estimate injury profiles and personnel status
- Equivalent dose to the skin due to contamination



## MODEL ASSUMPTIONS

## Overarching Model Assumptions

- Human response can be modeled over time as a function of dose-related signs and symptoms
  - Dose-related signs and symptoms apply for all doses/insults in a specified dose/insult range
- Human response to an exposure can be represented by the median individual in each dose/insult band
- Prior to exposure, individuals are in perfect health
- 70 kilogram man, breathing 15 liters per minute (moderate exertion)
- Human response is modeled as primary response to prompt, instantaneous insults
  - At this time no decision has been made on how to account for dose protraction in the AMedP-8(C) human response models
  - Human response for the entire exposed population begins simultaneously immediately following the radiological event
  - Human response does not include secondary, higher order, or indirect effects except as specifically noted



## Overarching Model Assumptions (cont'd)

- Severity of signs and symptoms resulting from combined insults is interactive
- While other signs and symptoms occur, the signs and symptoms manifested in the represented physiological systems are those systems most likely to cause an exposed individual to seek medical attention and thereby become a loss to the organization
- Contamination specific:
  - Clothing prevents direct contact with radioactive material; only hands and face are considered
  - Beta radiation only
  - Skin (radiological) injury will not occur quickly enough to cause KIA or DOW within time frame of interest

# RADIOLOGICAL DOSE BANDS



## Radiation Dose Range

| Dose Range (Gy) | Description |
|---|---|
| **0 – 1.25** | No observable effect |
| **1.25 – 3** | A slight decrease in white blood cell and platelet count with possible beginning symptoms of bone marrow damage; survival is >90 percent unless there are other injuries |
| **3 – 5.3** | Moderate to severe bone marrow damage occurs; lethality ranges from $LD_{5/60}$ to $LD_{10/60}$ to $LD_{50/60}$; these patients require greater than 30 days recovery, but other injuries would increase the injury severity and possible lethality |
| **5.3 – 8.3** | Severe bone marrow damage occurs; lethality ranges from $LD_{50/60}$ to $LD_{99/60}$; death occurs within 3.5 to 6 weeks with the radiation injury alone but is accelerated with other injuries; with other injuries they may die within 2 weeks |
| **> 8.3** | Bone marrow pancytopenia and moderate intestinal damage occur including diarrhea; death is expected within 2-3 weeks; with other injuries they may die within 2 weeks; at higher doses, combined gastrointestinal and bone marrow damage occur with hypotension and death is expected within 1-2.5 weeks or if other injuries are also present, patients may die within 6 days |



Derived from NATO. *AMedP-8. Op. cit.* p. 3-9; and NATO. *STANAG 2083.*

## Skin (Radiological) Dose Range

| Skin Cont. Dose Range (Gy) | Description |
|---|---|
| < 2 | No observable effect |
| 2 – 15 | 2 – 5 wks post exposure: redness of skin, slight edema, possible increased pigmentation; 6 – 7 wks post exposure: dry desquamation |
| 15 – 40 | Immediate sensation of heat, itching; 1 – 3 wks post exposure: redness, sense of heat, edema; 5 – 6 wks post exposure: subcutaneous tissue edema, blisters, moist desquamation; late effects (>10 wks) |
| 40 – 550 | Immediate pain, tingling for 1 – 2 days; 1 – 2 wks post exposure: redness, blisters, sense of heat, edema, pigmentation, erosions, ulceration, severe pain; severe late effects (>10 wks) |
| > 550 | Immediate pain, tingling, swelling; 1 – 4 days post exposure: blisters, early ischemia, substantial pain; tissue necrosis within 2 weeks, substantial pain |



S/S maps are based on signs/symptoms progressions detailed in CDC., *Cutaneous Radiation Injury: Fact Sheet for Physicians.*



## EXTERNAL RADIATION & SKIN (RADIOLOGICAL) SYMPTOMS SEVERITY LEVELS & MAPS

## Severity Definitions

| | Degrees | Description |
|---|---|---|
| 0 | N.O.E. | No observable effect |
| 1 | Mild | Disease or wounds manifesting signs and symptoms of such severity that individuals can care for themselves or be helped by untrained personnel and their ability to conduct the assigned mission may not be impacted by the manifested signs and symptoms |
| 2 | Moderate | Disease or wounds manifesting signs and symptoms of such severity that medical care may be required; general condition permits treatment as outpatient and some continuing care and relief of pain may be required before definitive care is given; condition may be expected to interrupt or preclude ability to conduct the assigned mission |
| 3 | Severe | Disease or wounds manifesting signs and symptoms of such severity that there is cause for immediate concern but there is no imminent danger to life; individual is acutely ill and likely requires hospital care. Indicators are questionable – condition may or may not reverse without medical intervention; individual is unable to conduct the assigned mission due to severity of signs and symptoms |
| 4 | Very Severe | Disease or wounds manifesting signs and symptoms of such severity that life is imminently endangered. Indicators are unfavorable – condition may or may not reverse even with medical intervention; prognosis is lethality without medical intervention; individual is unable to conduct the assigned mission and is unexpected to return to the mission due to severity of signs and symptoms |

## Symptoms Systems

| | Irradiation | Contamination |
|---|---|---|
| Cardiovascular | X | |
| Immune | X | |
| Lower Gastrointestinal | X | |
| Skin (Radiological) | | X |
| Upper Gastrointestinal | X | |

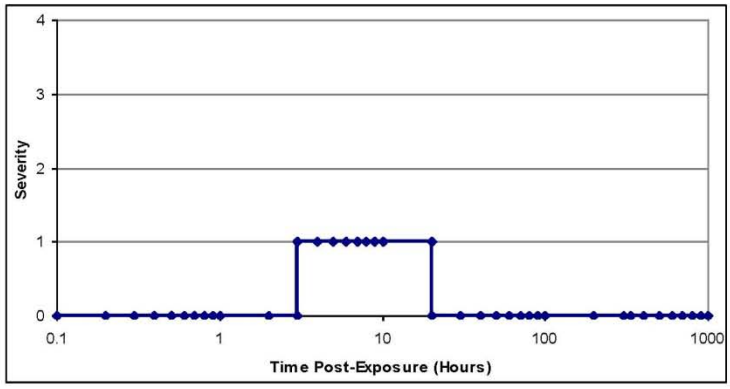
## Symptoms Severities

| Signs / Symptoms Severity | Upper GI Symptoms | Lower GI Symptoms |
|---|---|---|
| 0 | No observable effect | No observable effect |
| 1 | Upset stomach and nausea; watering mouth and frequent swallowing to avoid vomiting | Abdominal pain or cramps; occasional diarrhea and uncomfortable urge to defecate |
| 2 | Episodes of vomiting, possibly including dry heaves; severe nausea and possibility of continued vomiting | Frequent diarrhea and cramps; continuing defecation |
| 3 | Protracted or continued vomiting, including dry heaves | Uncontrollable diarrhea and urination; painful cramps |
| 4 | | |

26 June 2008 12

## Radiological S/S Map for Radiation Dose Range of 1.25–3 Gy

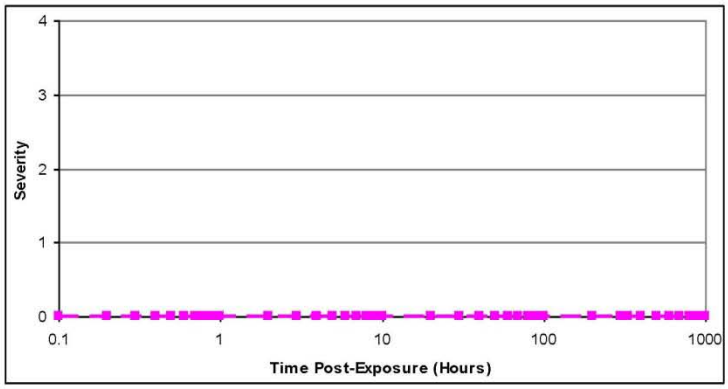
### UPPER GI




26 June 2008 13

## Radiological S/S Map for Radiation Dose Range of 1.25–3 Gy

### LOWER GI




26 June 2008 14

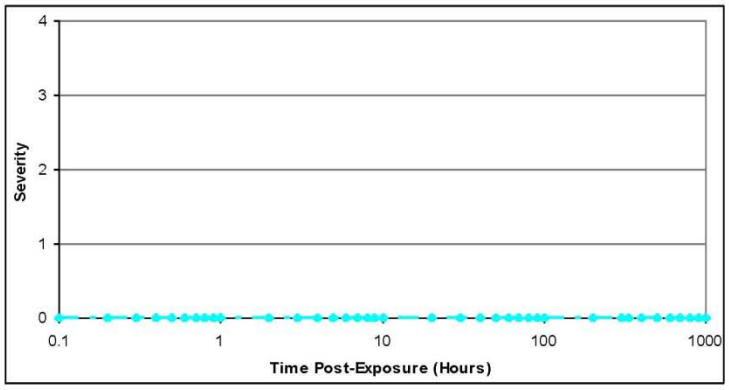
## Symptoms Severities

| Signs / Symptoms Severity | Cardiovascular Symptoms | Immune Symptoms |
|---|---|---|
| 0 | No observable effect | No observable effect |
| 1 | Slight feeling of light headedness | Slight fever and headache |
| 2 | Unsteadiness upon standing quickly; possible micro-hemorrhaging | Increased rate of infection; aching joints; fever; sores in mouth/throat; possible skin lesions |
| 3 | Severe dizziness; faints upon standing quickly; may have difficulty stopping any bleeding | High fever results in shakes, chills and aches all over |
| 4 | Shock; rapid and shallow breathing; skin cold, clammy and very pale; difficulty or inability to stop any bleeding; crushing chest pain | Delirium from fever; overwhelming infections |

26 June 2008 15

## Radiological S/S Map for Radiation Dose Range of 1.25–3 Gy

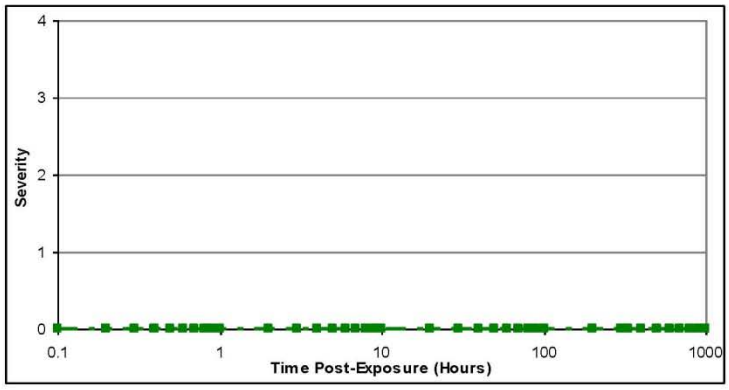
### CARDIOVASCULAR




26 June 2008 16

## Radiological S/S Map for Radiation Dose Range of 1.25–3 Gy

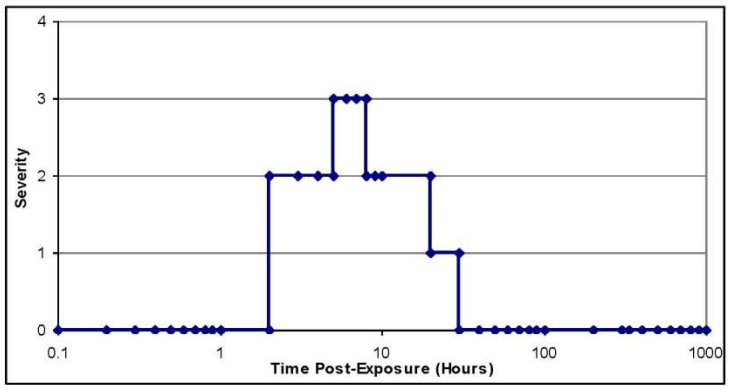
### IMMUNE




26 June 2008 17

## Radiological S/S Map for Radiation Dose Range of 3–5.3 Gy

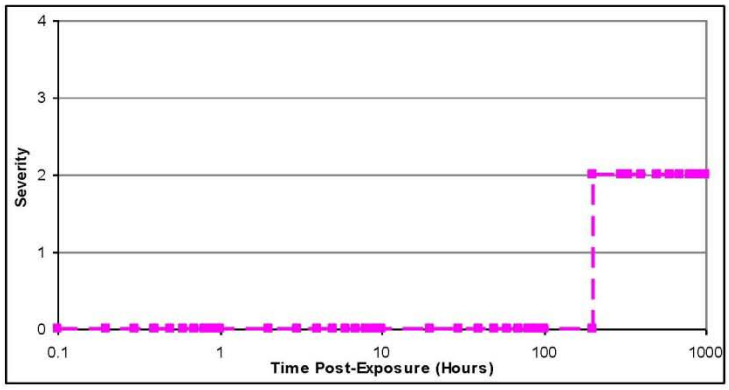
### UPPER GI




26 June 2008 18

## Radiological S/S Map for Radiation Dose Range of 3–5.3 Gy

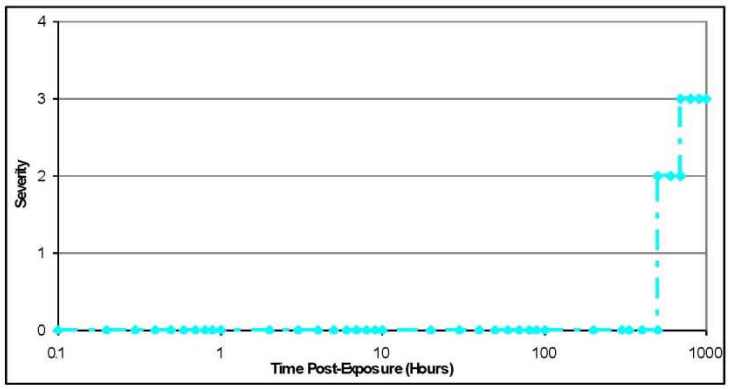
### LOWER GI




26 June 2008 19

## Radiological S/S Map for Radiation Dose Range of 3–5.3 Gy

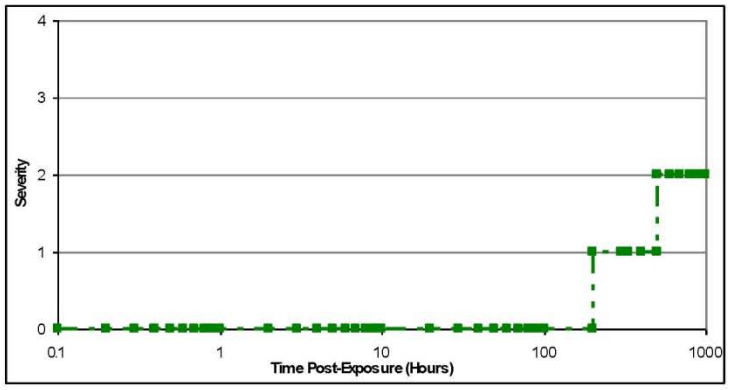
### CARDIOVASCULAR




26 June 2008 20

## Radiological S/S Map for Radiation Dose Range of 3–5.3 Gy

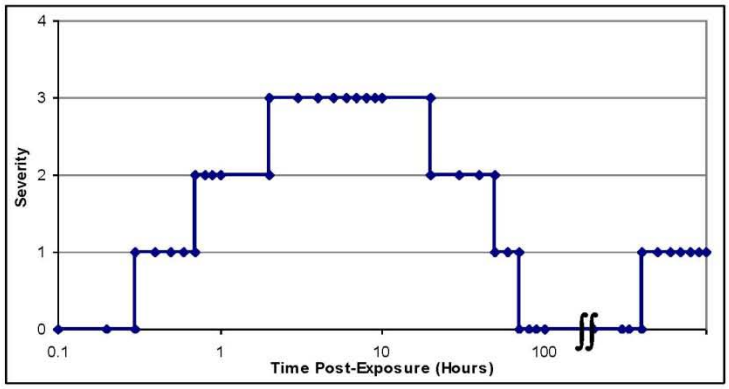
### IMMUNE




26 June 2008 21

## Radiological S/S Map for Radiation Dose Range of 5.3–8.3 Gy

### UPPER GI

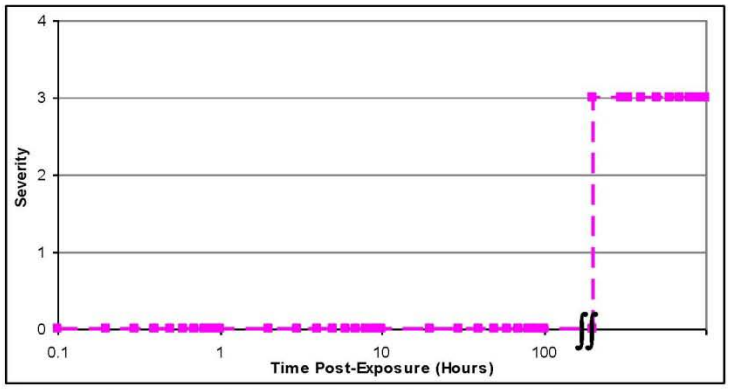



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 22

## Radiological S/S Map for Radiation Dose Range of 5.3–8.3 Gy

### LOWER GI

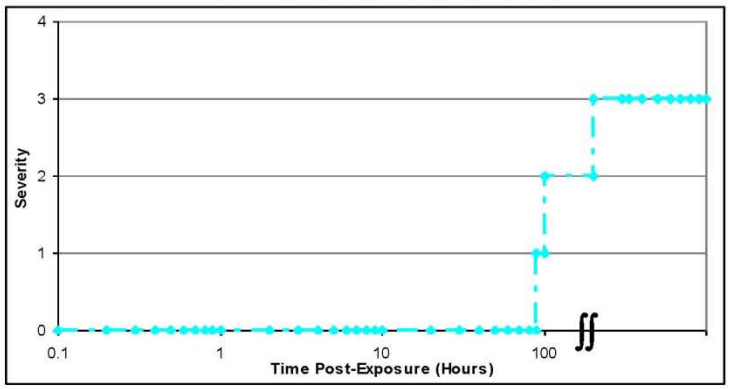



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 23

## Radiological S/S Map for Radiation Dose Range of 5.3–8.3 Gy

### CARDIOVASCULAR

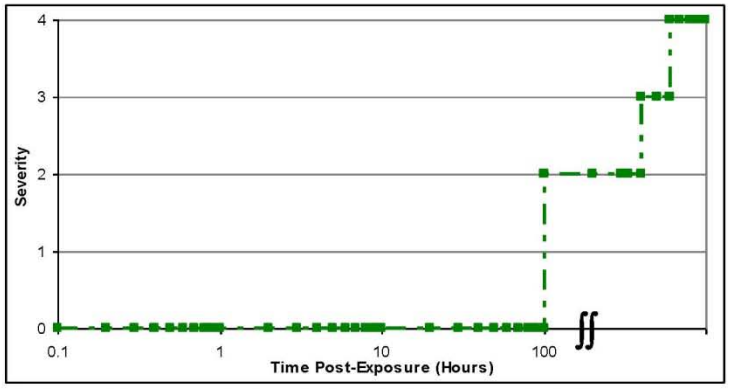



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 24

## Radiological S/S Map for Radiation Dose Range of 5.3–8.3 Gy

### IMMUNE

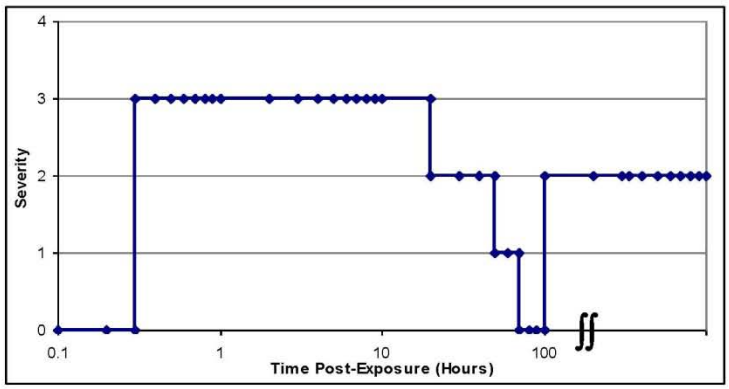



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 25

## Radiological S/S Map for Radiation Dose Range of > 8.3 Gy

### UPPER GI

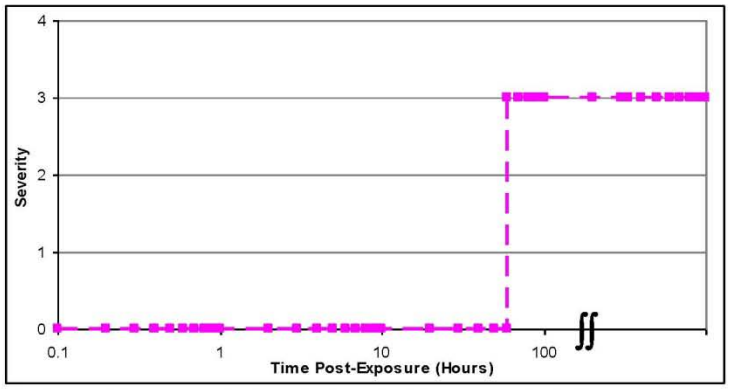



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 26

## Radiological S/S Map for Radiation Dose Range of > 8.3 Gy

### LOWER GI

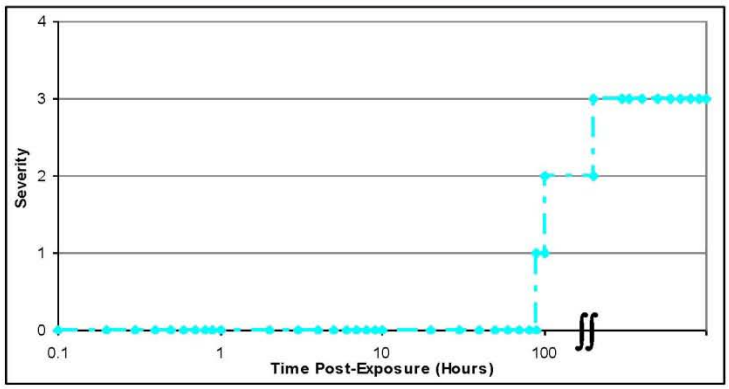



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 27

## Radiological S/S Map for Radiation Dose Range of > 8.3 Gy

### CARDIOVASCULAR

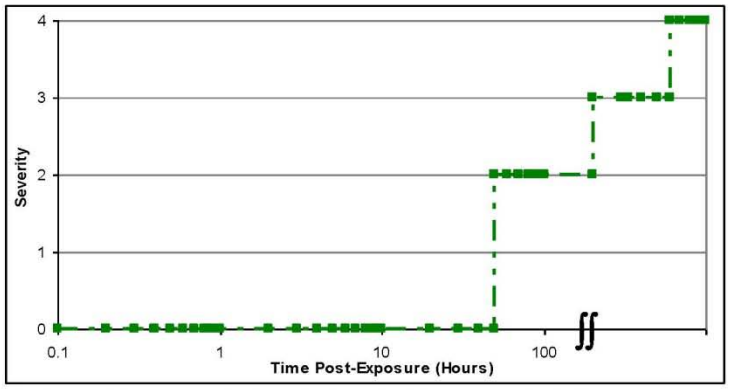



For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 28

## Radiological S/S Map for Radiation Dose Range of > 8.3 Gy

### IMMUNE




For doses > 5 Gy, time to death is calculated; the injury progression is followed as described until time of death, which may occur up to or later than 6 weeks

26 June 2008 29

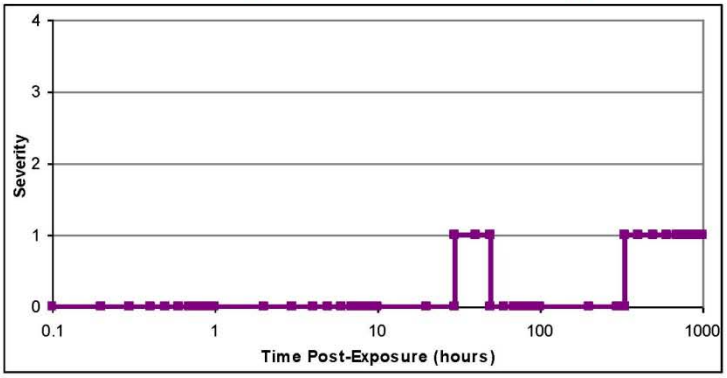
## Signs/Symptoms Severities

| Severity | Skin (Radiological) Signs/Symptoms |
|---|---|
| 0 | No observable effect |
| 1 | Itching, sensation of heat, redness, slight edema |
| 2 | Subcutaneous edema, blister formation, epilation |
| 3 | Ischemia (tissue turns white then dark), ulceration, substantial pain, possible skin necrosis |
| 4 | |

26 June 2008 30

## Radiological S/S Map for Equivalent Dose to Skin Range of 2–15 Gy

### SKIN (RADIOLOGICAL)

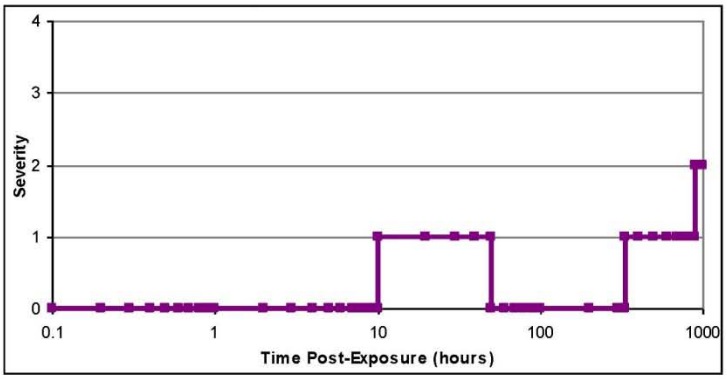



S/S maps are based on signs/symptoms progressions detailed in CDC., *Cutaneous Radiation Injury: Fact Sheet for Physicians*. Table 1 page 3

26 June 2008 31

## Radiological S/S Map for Equivalent Dose to Skin Range of 15–40 Gy

### SKIN (RADIOLOGICAL)

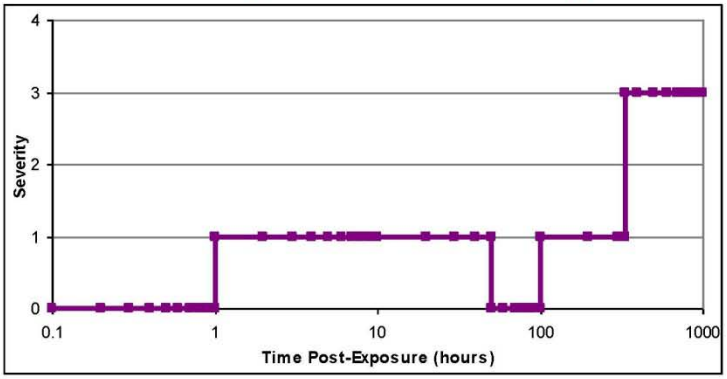



S/S maps are based on signs/symptoms progressions detailed in CDC., *Cutaneous Radiation Injury: Fact Sheet for Physicians*. Table 1 page 3



## Radiological S/S Map for Equivalent Dose to Skin Range of 40–550 Gy

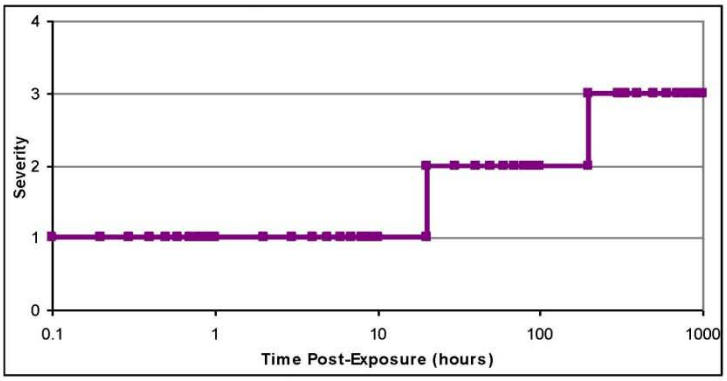
### SKIN (RADIOLOGICAL)




S/S maps are based on signs/symptoms progressions detailed in CDC., *Cutaneous Radiation Injury: Fact Sheet for Physicians*. Table 1 page 4

## Radiological S/S Map for Equivalent Dose to Skin Range of > 550 Gy

### SKIN (RADIOLOGICAL)




S/S maps are based on signs/symptoms progressions detailed in CDC., *Cutaneous Radiation Injury: Fact Sheet for Physicians*. Table 1 page 5



## EXAMPLE: RADIOLOGICAL HUMAN RESPONSE

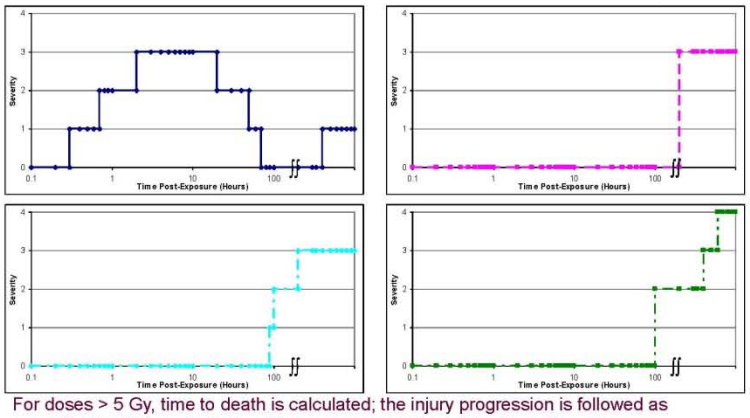
## Example Case: Radiological

- Radiological Example Case Exposures
  - Total Effective External Radiation Dose: 6 Gy
  - Equivalent Dose to Skin: 48 Gy



## Example Case: Radiological

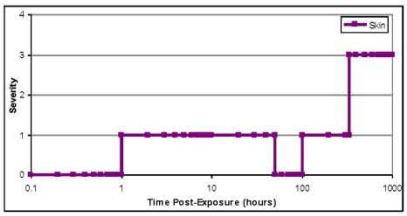
- Total Effective External Radiation Dose: 6 Gy




For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

## Example Case: Radiological

- Equivalent Dose to Skin: 48 Gy



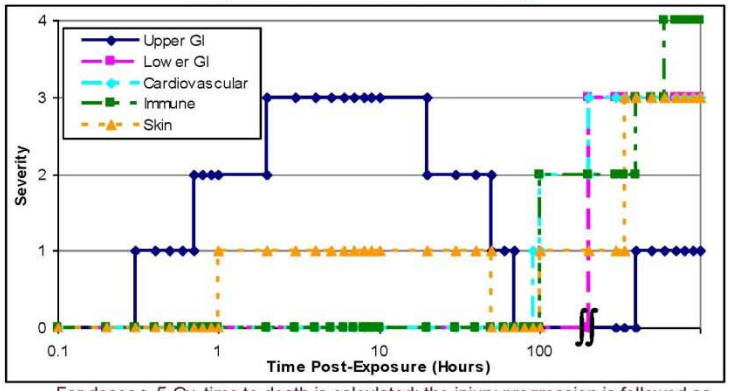

S/S maps are based on signs/symptoms progressions detailed in CDC., *Cutaneous Radiation Injury: Fact Sheet for Physicians*. Table 1 page 3



## Example Case: Radiological

- Radiological Injury Progression

**Total Effective External Radiation Dose: 6 Gy &**
**Equivalent Dose to Skin: 48 Gy**

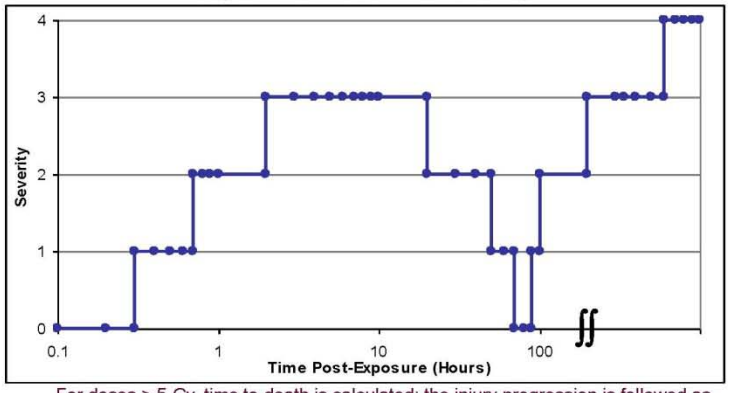



For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

## Example Case: Radiological

- Radiological Injury Progression

**Total Effective External Radiation Dose: 6 Gy &**
**Equivalent Dose to Skin: 48 Gy**




26 June 2008

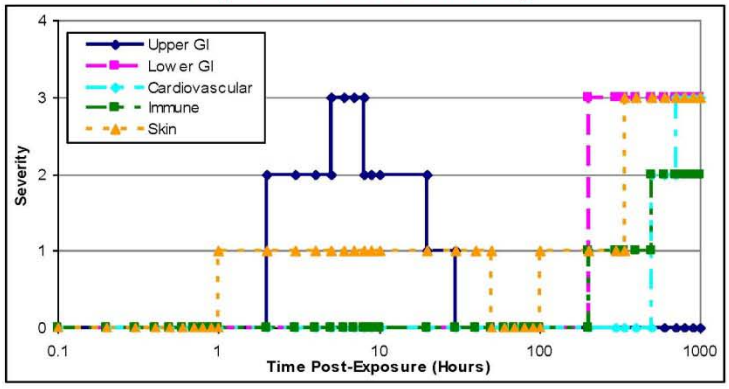
For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

40

## Example Case: Radiological

- Radiological Injury Progression

**Total Effective External Radiation Dose: 4 Gy &**
**Equivalent Dose to Skin: 48 Gy**



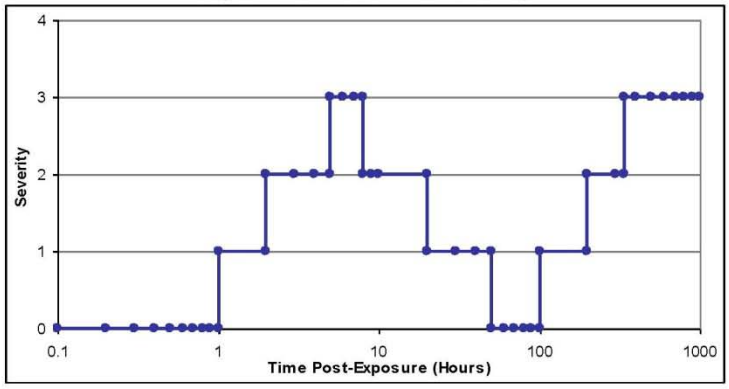

26 June 2008

41

## Example Case: Radiological

- Radiological Injury Progression

**Total Effective External Radiation Dose: 4 Gy &**
**Equivalent Dose to Skin: 48 Gy**








# Questions?

## Contact

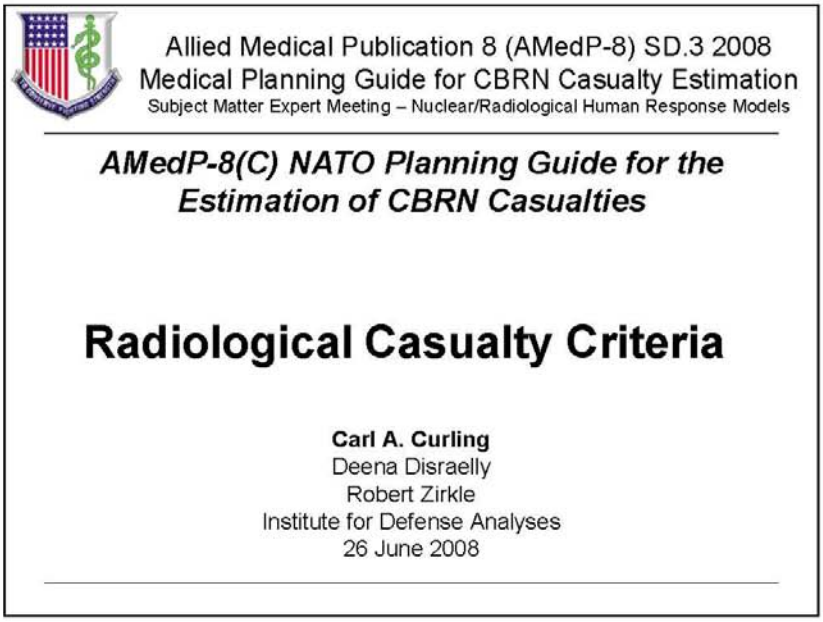
Carl Curling, Sc.D. Deena Disraelly Robert Zirkle, PhD

Strategy, Forces & Resources Division
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
FAX – 703-845-2255

| ccurling@ida.org | ddisrael@ida.org | rzirkle@ida.org |
|---|---|---|
| 703-578-2814 | 703-845-6685 | 703-845-2038 |

THIS PAGE INTENTIONALLY LEFT BLANK

## F. Radiological Casualty Criteria – *Briefing*

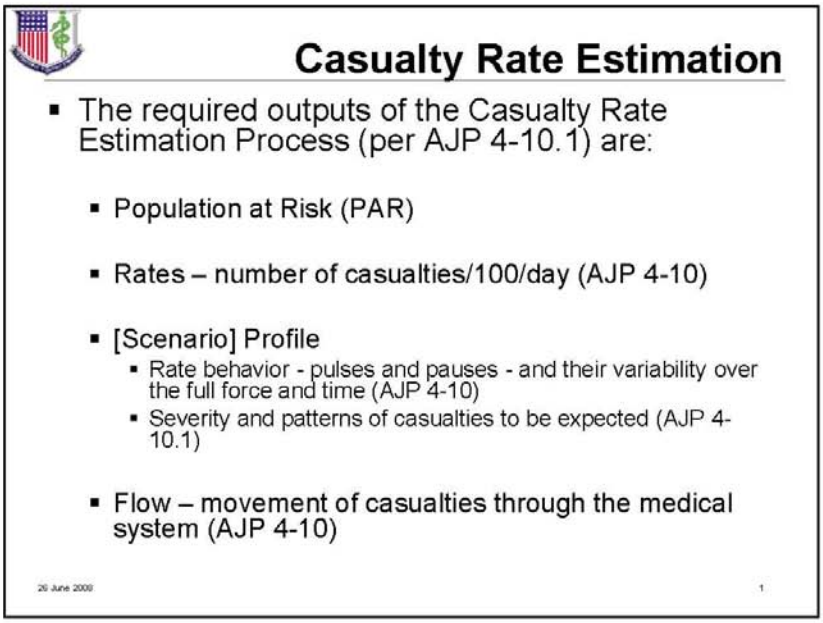


Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

*AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties*

**Radiological Casualty Criteria**

**Carl A. Curling**
Deena Disraelly
Robert Zirkle
Institute for Defense Analyses
26 June 2008



**Casualty Rate Estimation**

- The required outputs of the Casualty Rate Estimation Process (per AJP 4-10.1) are:
  - Population at Risk (PAR)
  - Rates – number of casualties/100/day (AJP 4-10)
  - [Scenario] Profile
    - Rate behavior - pulses and pauses - and their variability over the full force and time (AJP 4-10)
    - Severity and patterns of casualties to be expected (AJP 4-10.1)
  - Flow – movement of casualties through the medical system (AJP 4-10)

26 June 2008 1

## AMedP-8 Human Response Models

The proposed Human Response Models:

- Estimates the personnel status over time after exposure to some Chemical, Biological, Radiological, or Nuclear agent or effect
- Allow for estimation of:
  - KIA as a function of specific levels of effect
  - WIA at the time at which signs, symptoms and/or injury reach a specified severity level or as a function of specific effect levels
  - DOW at some time after agent or effect exposure as a function of an agent/effect-related estimation or a specified severity level
- Also allows for a description of effects or injury severities over time



## CASUALTY RATE ESTIMATOR OUTPUTS CHARACTERIZATION

## [Scenario] Profile

A. Casualty Type
- KIA, WIA, DOW

Amplifying WIA Information:

B. Injury or Disease Severity
- Mild, Moderate, Severe, Very Severe at organism level

**C. Injury or Disease Severity by Effect**
- **Mild, Moderate, Severe, Very Severe for Radiological at organism level**

D. System
- Upper GI, Lower GI, Skin (Radiological), Immune, Cardiovascular

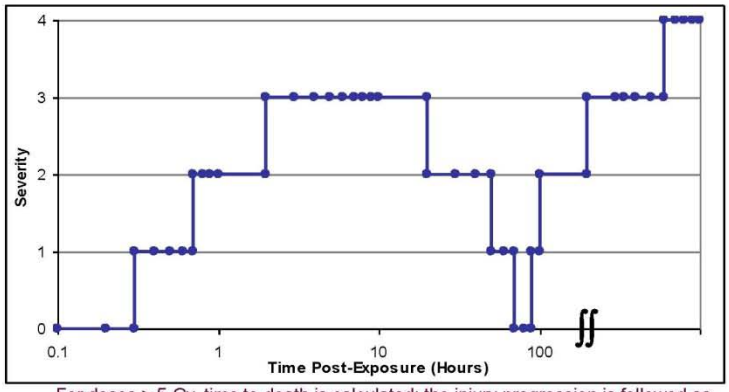
E. System Severity
- Mild, Moderate, Severe, Very Severe for each of:
- Upper GI, Lower GI, Skin (Radiological), Immune, Cardiovascular

F. Sign / Symptom Description
- Vomiting, difficulty breathing, partial thickness (2nd degree) and epidermal burns (1st degree), …



## Illustrative Example

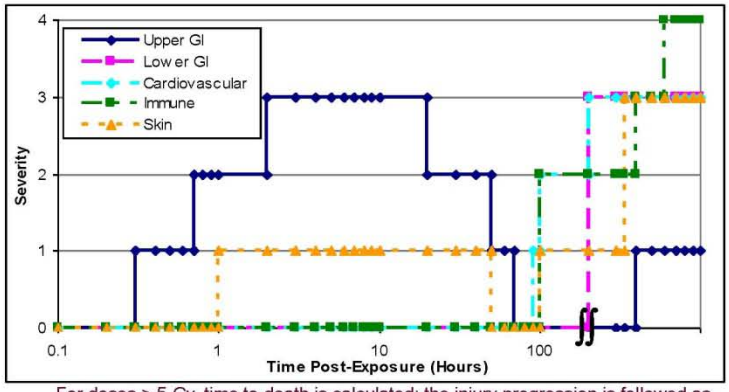
**Exposure of 6 Gy external and 48 Gy to the skin**




For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks

## Illustrative Example

**Exposure of 6 Gy external and 48 Gy to the skin**




For doses > 5 Gy, time to death is calculated; the injury progression is followed as prescribed until time of death, which may occur up to or later than 6 weeks



## Illustrative Example [Scenario] Profile

A. Casualty Type
   - WIA

B. Injury or Disease Severity
   - WIA, Mild

**C. Injury or Disease Severity by Effect**
   - WIA, Mild Radiological

D. System
   - Upper GI, Skin (Radiological), with late Cardiovascular and Immune

## Illustrative Example [Scenario] Profile

E. System Severity
- 18 minutes (0.3 hours) Post-Exposure
  - WIA with mild upper GI signs and symptoms
- 1 hour Post-Exposure
  - WIA with moderate upper GI and mild skin (radiological) signs and symptoms
- 2 hours Post-Exposure
  - WIA with severe upper GI and mild skin (radiological) signs and symptoms
- 11 hours Post-Exposure
  - Resolving to mild …
- 1-6 weeks Post-Exposure
  - Relapse of mild skin (radiological) signs and symptoms progressing to severe, and onset of mild to moderate cardiovascular and immune signs and symptoms progressively becoming worse



## Illustrative Example [Scenario] Profile

F. Sign / Symptom Description
- 1 hour Post-Exposure
  - Episodes of vomiting, possibly including dry heaves; severe nausea and possibility of continued vomiting
  - Itching, sensation of heat, redness, slight edema

## Recommendation

[Scenario] Profile: The description of CBRN casualties by type, and for WIA; severity and disease or injury type (e.g. KIA, Severe Radiological WIA, Moderate Radiological WIA…)

Provides information on personnel status for the operational planner and injury types for the medical planner

- Time personnel are lost to unit
- Type of injury and implied medical requirement



## RECOMMENDED VALUES

## Recommended Casualty Definitions

**AAP-6 Definitions:**

- WIA - "In relation to personnel, any person who is lost to his organization by reason of having been declared dead, wounded, diseased, detained, captured or missing."
- DOW - "A battle casualty who dies of wounds or other injuries received in action, after having reached a medical treatment facility."
- KIA - "A battle casualty who is killed outright or who dies as a result of wounds or other injuries before reaching a medical treatment facility."

**Model Implementation:**

- WIA - Individual whose injury profile severity ≥ 1
- DOW - Individual whose injury profile severity = 4 for 15 minutes or 2 consecutive reporting times, or whose time to death from irradiation injury is exceeded (whichever is earlier)
- KIA - Individual who meets the criteria for DOW before reaching a medical treatment facility (appr. 30 minutes post-release)





# Questions?

## Contact

Carl Curling, Sc.D. Deena Disraelly Robert Zirkle, PhD

Strategy, Forces & Resources Division
Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882
FAX – 703-845-2255

| ccurling@ida.org | ddisrael@ida.org | rzirkle@ida.org |
|---|---|---|
| 703-578-2814 | 703-845-6685 | 703-845-2038 |

## G. The German Radiation Accident Database – SEARCH – *Briefing*

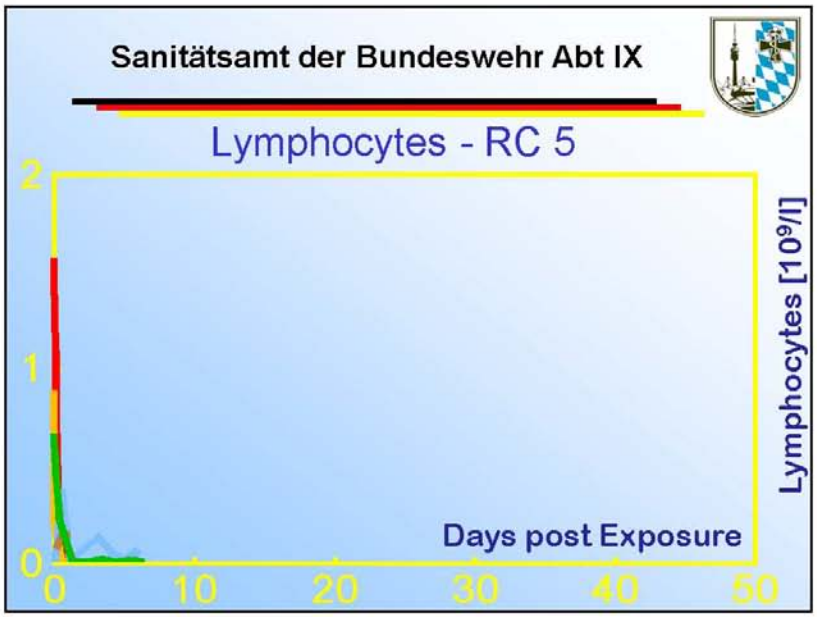

Sanitätsamt der Bundeswehr Abt IX

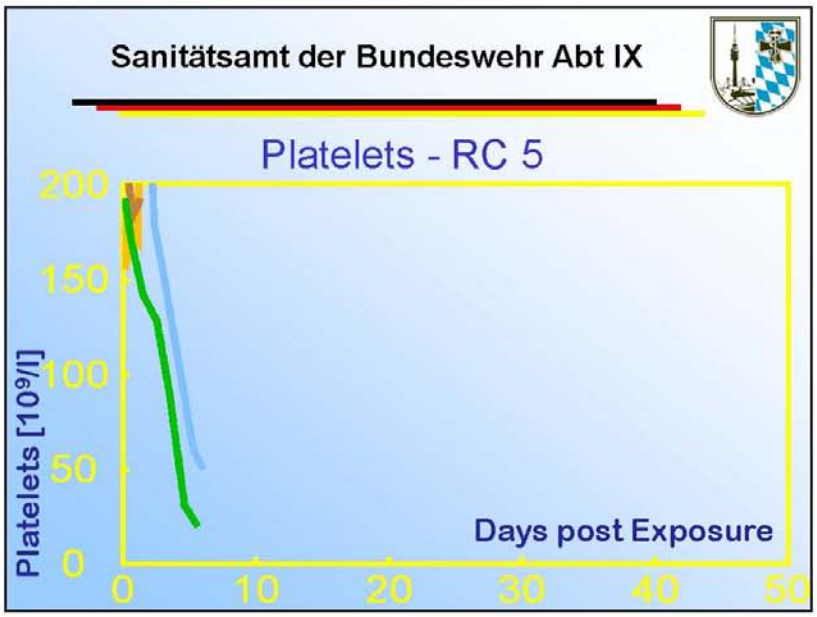
## Response Category 5

- 5 out of 5 cases
- Los Alamos III, Wood River Junction, Moskau, Chelyabinsk I und II
- Granulocytes: Decline 3-5 d
- Lymphocytes: ~ 0/l 0-1 d
- Platelets: < $50 \cdot 10^9$/l 5-7d

Sanitätsamt der Bundeswehr Abt IX

## Granulocytes - RC 5


Sanitätsamt der Bundeswehr Abt IX
Lymphocytes - RC 5
2
1
0
Lymphocytes [10⁹/l]
Days post Exposure
0
10
20
30
40
50


Sanitätsamt der Bundeswehr Abt IX
Platelets - RC 5
200
150
100
50
0
Platelets [10⁹/l]
Days post Exposure
0
10
20
30
40
50

Sanitätsamt der Bundeswehr Abt IX

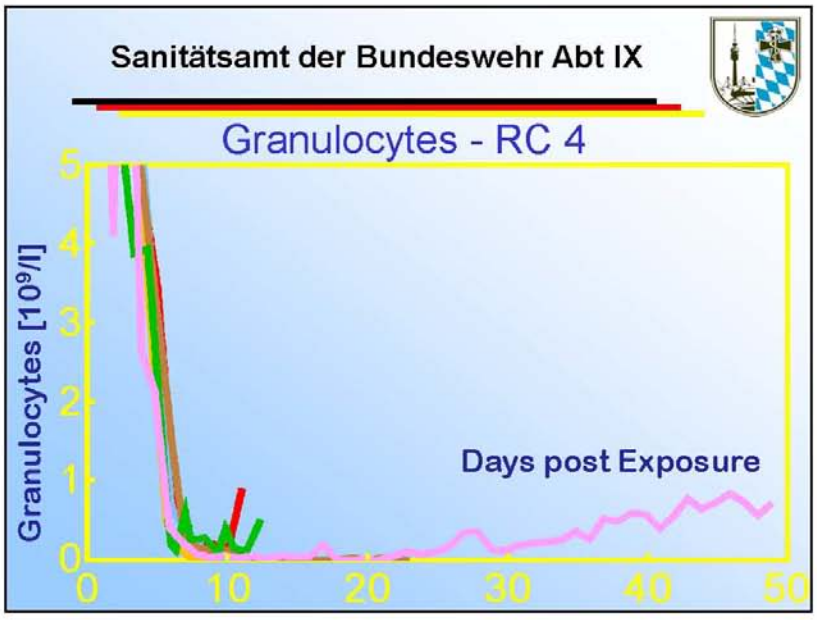
## Additional Information (RC 5)

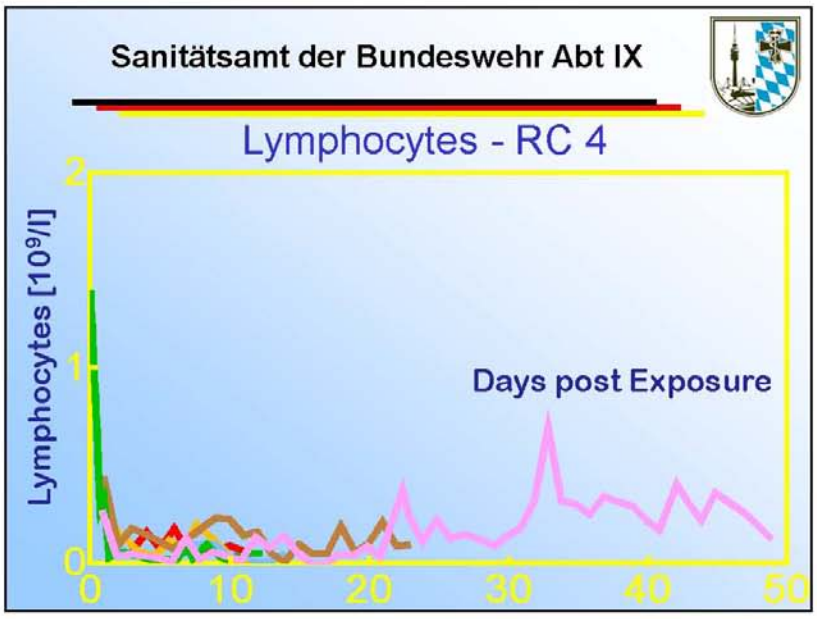
- Dose estimate (mean): > 20 Sv
- All patients died within 2-7 days of exposure (Ø: 4,5 days)
- Nausea and vomiting: 5 of 5
- CNS symptomatology: 5 of 5
- GITsymptomatology: 5 of 5

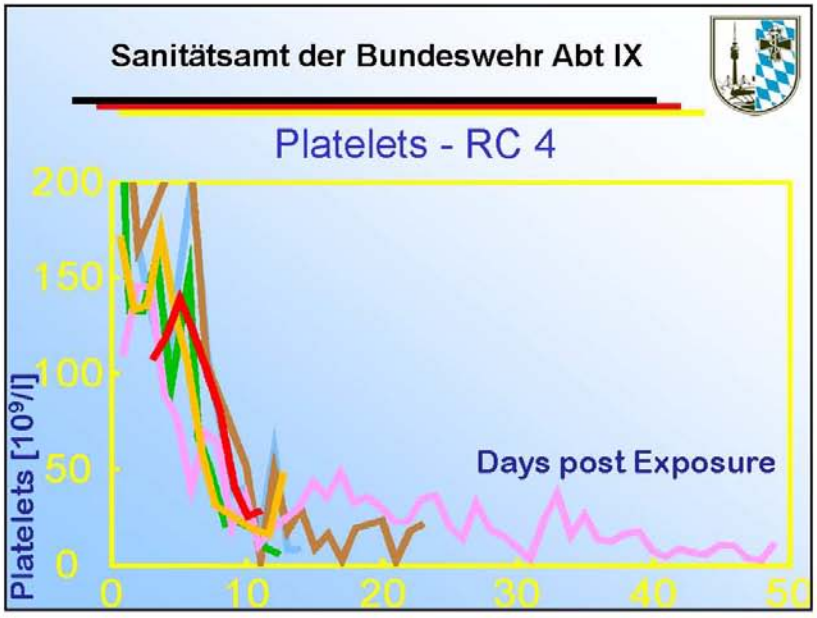
Sanitätsamt der Bundeswehr Abt IX

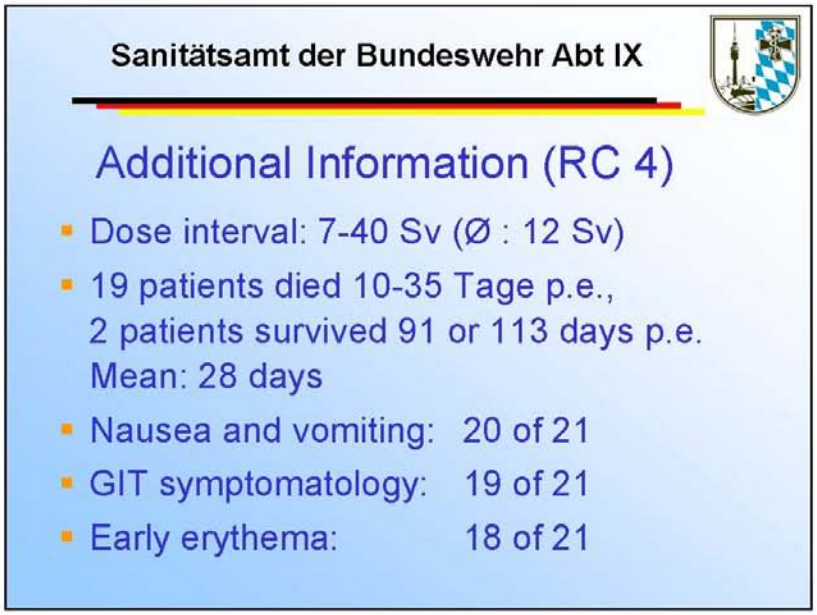
## Response Category 4

- 6 out of 21 cases
- Brescia, Kjeller, Chernobyl (2 cases), Moscow, Nyesvidsch
- Granulocytes: Decline 4-6 d
- Lymphocytes: < $0.2 \cdot 10^9$/l 0-2 d
- Platelets: < $50 \cdot 10^9$/l 6-9 d


Sanitätsamt der Bundeswehr Abt IX
Granulocytes - RC 4
Granulocytes [10⁹/l]
Days post Exposure
0
1
2
3
4
5
0
10
20
30
40
50


Sanitätsamt der Bundeswehr Abt IX
Lymphocytes - RC 4
Lymphocytes [10⁹/l]
Days post Exposure
0
1
2
0
10
20
30
40
50


Sanitätsamt der Bundeswehr Abt IX
Platelets - RC 4
200
150
100
50
0
Platelets [10⁹/l]
Days post Exposure
0
10
20
30
40
50

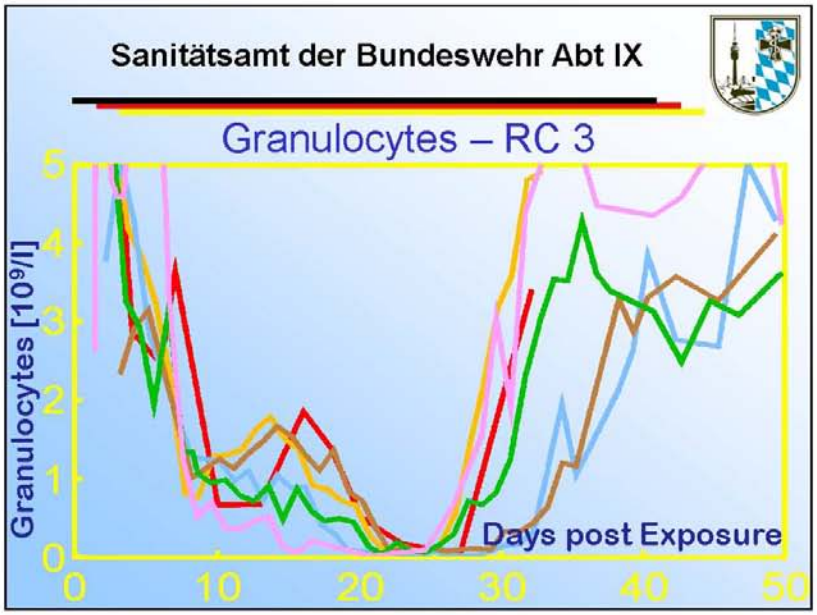

Sanitätsamt der Bundeswehr Abt IX
Additional Information (RC 4)
Dose interval: 7-40 Sv (Ø : 12 Sv)
19 patients died 10-35 Tage p.e.,
2 patients survived 91 or 113 days p.e.
Mean: 28 days
Nausea and vomiting: 20 of 21
GIT symptomatology: 19 of 21
Early erythema: 18 of 21

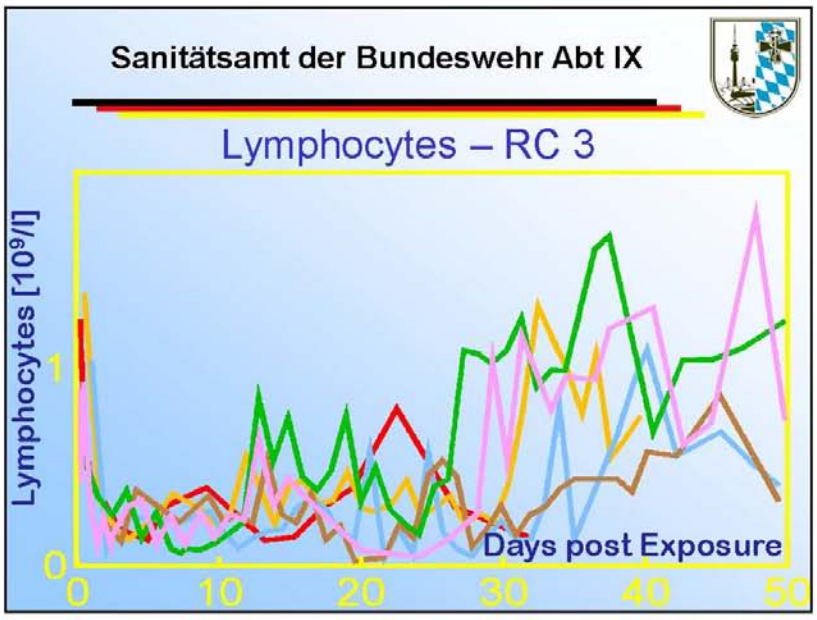
Sanitätsamt der Bundeswehr Abt IX

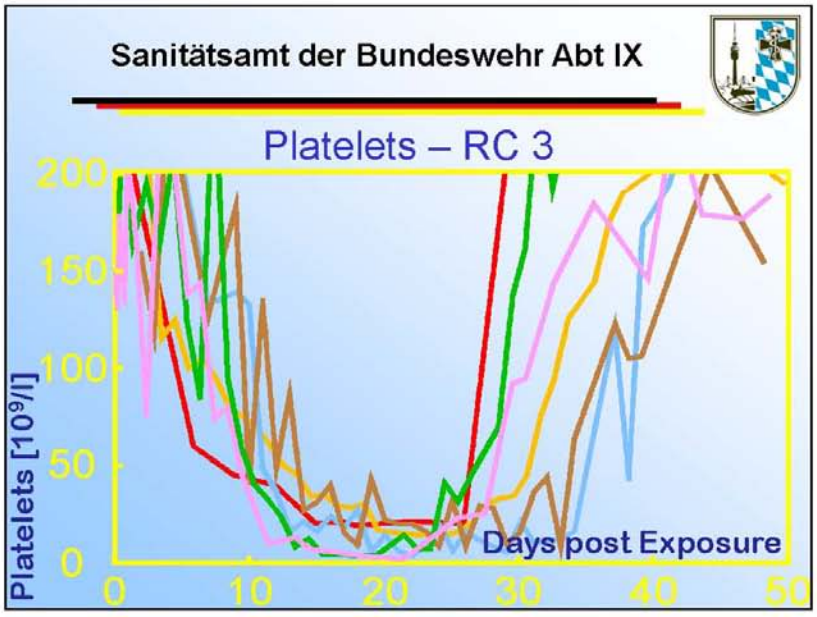
## Response Category 3

- 6 of 40 cases
- Vinca, Mol, Chernobyl (2 cases), Moscow I, Moscow II
- Granulocytes: nadir20-30 d
  abortive rise 6-8 d
- Lymphocytes: ~ $0.3*10^9$/l 1-9 d
- Platelets: < $50*10^9$/l 12-31 d

Sanitätsamt der Bundeswehr Abt IX




Sanitätsamt der Bundeswehr Abt IX
Lymphocytes – RC 3
Lymphocytes [10⁹/l]
1
0
Days post Exposure
0
10
20
30
40
50

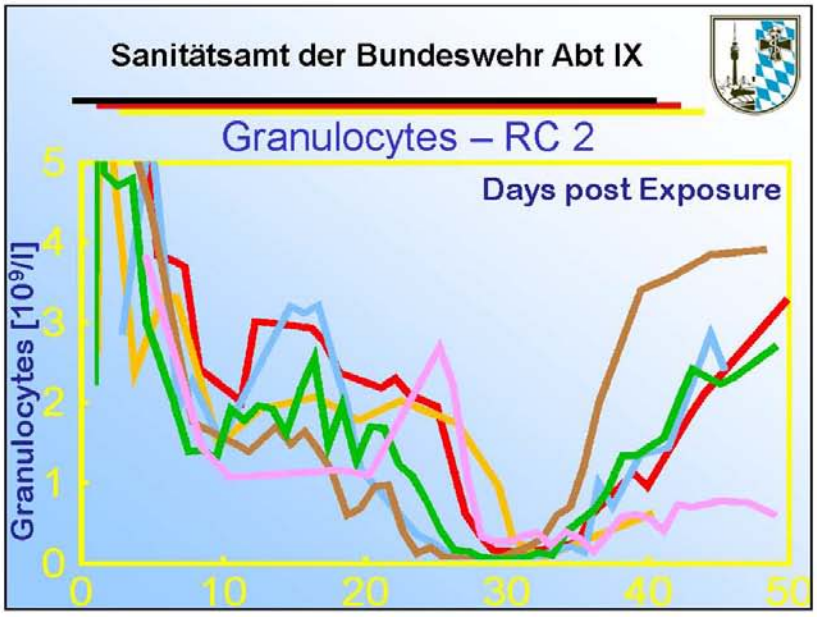

Sanitätsamt der Bundeswehr Abt IX
Platelets – RC 3
200
150
100
50
0
Platelets [10⁹/l]
Days post Exposure
0
10
20
30
40
50

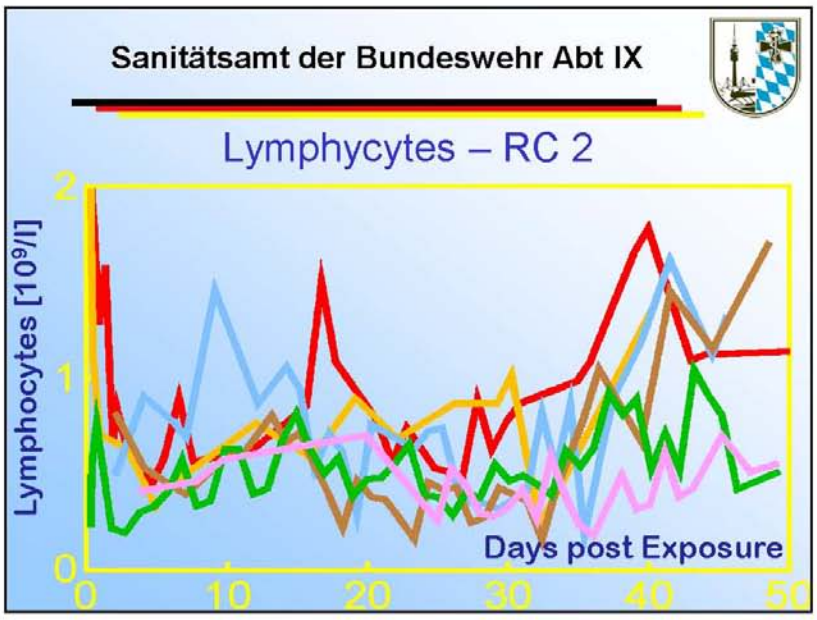
Sanitätsamt der Bundeswehr Abt IX

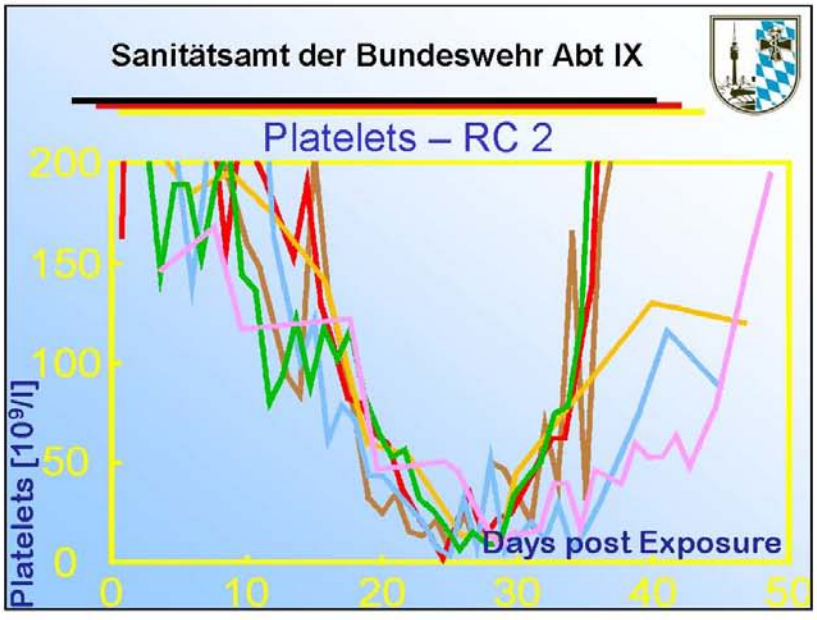
## Response Category 2

- 6 of 61 cases
- Oak Ridge, Vinca, Moscow, Tomsk, Chernobyl (2 cases)
- Granulocytes: nadir25-35 d
  abortive rise 10-22 d
- Lymphocytes: ~ $0.8*10^9$/l 1-9 d
- Platelets: < $50*10^9$/l 18-35 d

Sanitätsamt der Bundeswehr Abt IX




Sanitätsamt der Bundeswehr Abt IX
Lymphycytes – RC 2
Lymphocytes [10⁹/l]
2
1
0
Days post Exposure
0
10
20
30
40
50

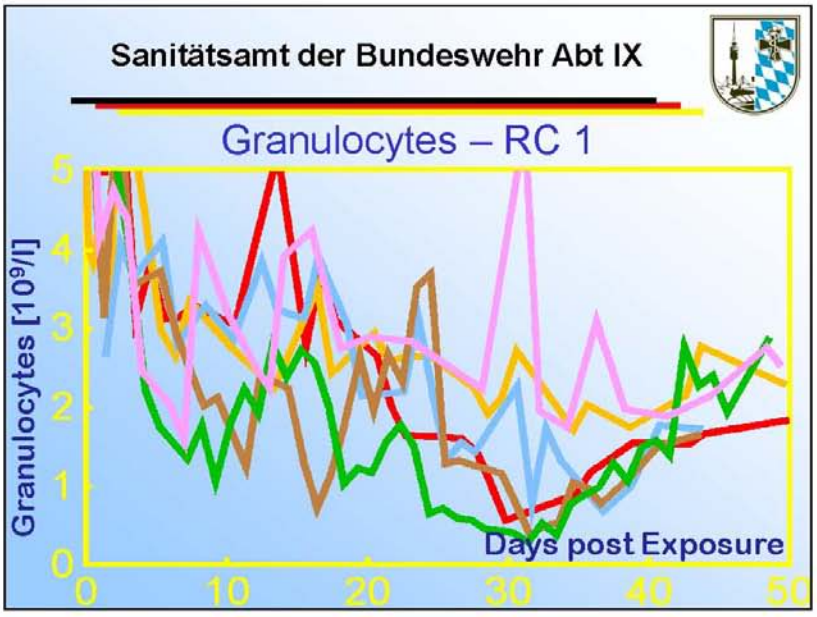

Sanitätsamt der Bundeswehr Abt IX
Platelets – RC 2
Platelets [10⁹/l]
200
150
100
50
0
Days post Exposure
0
10
20
30
40
50

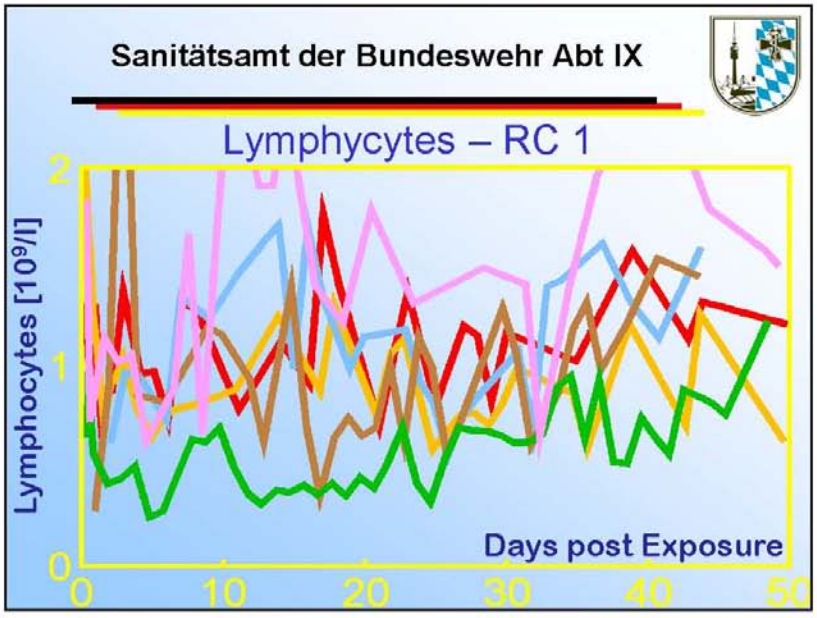
Sanitätsamt der Bundeswehr Abt IX

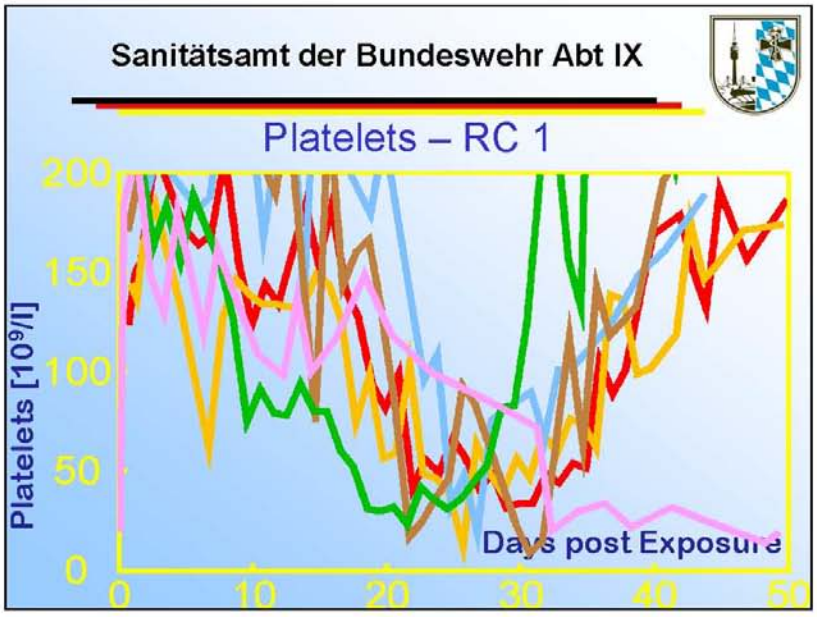
## Response Category 1

- 6 of 26 cases
- Oak Ridge (2 cases), Moscow, Chelyabinsk, Chernobyl (2 cases)
- Granulocytetopenia 10-40 d
- Lymphocytes: ~ $1.0*10^9$/l 1-9 d
- Platelets: < $50*10^9$/l 25-35 d

Sanitätsamt der Bundeswehr Abt IX



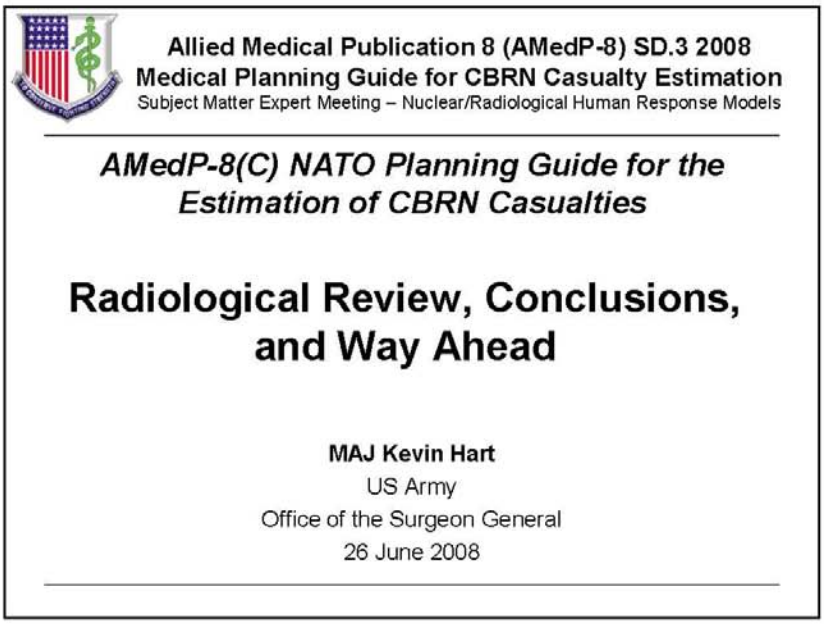

Sanitätsamt der Bundeswehr Abt IX
Lymphycytes – RC 1
Lymphocytes [10⁹/l]
2
1
0
Days post Exposure
0
10
20
30
40
50


Sanitätsamt der Bundeswehr Abt IX
Platelets – RC 1
Platelets [10⁹/l]
200
150
100
50
0
Days post Exposure
0
10
20
30
40
50


Sanitätsamt der Bundeswehr

THIS PAGE INTENTIONALLY LEFT BLANK

## H. Radiological Review, Conclusions, and Way Ahead – *Briefing*

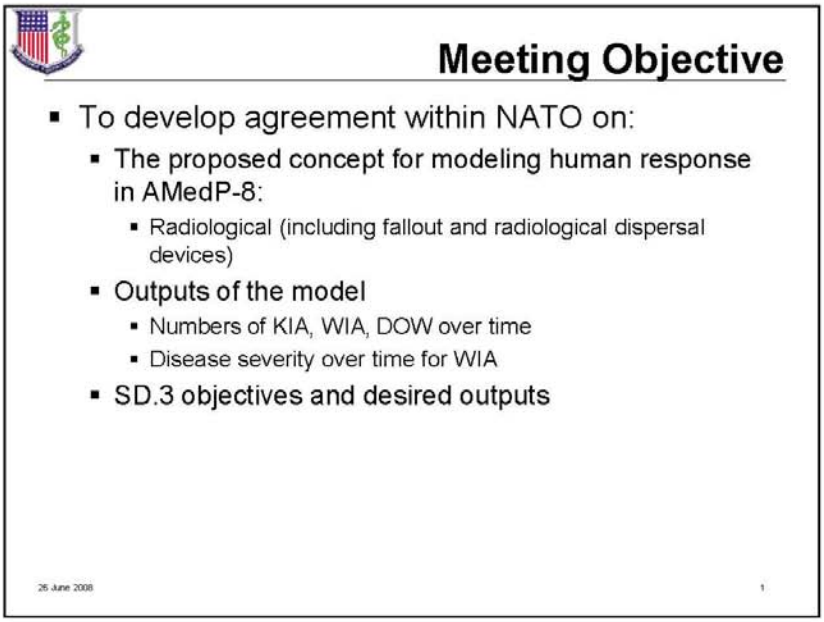


Allied Medical Publication 8 (AMedP-8) SD.3 2008
Medical Planning Guide for CBRN Casualty Estimation
Subject Matter Expert Meeting – Nuclear/Radiological Human Response Models

*AMedP-8(C) NATO Planning Guide for the Estimation of CBRN Casualties*

**Radiological Review, Conclusions, and Way Ahead**

**MAJ Kevin Hart**
US Army
Office of the Surgeon General
26 June 2008



**Meeting Objective**

- To develop agreement within NATO on:
  - The proposed concept for modeling human response in AMedP-8:
    - Radiological (including fallout and radiological dispersal devices)
  - Outputs of the model
    - Numbers of KIA, WIA, DOW over time
    - Disease severity over time for WIA
  - SD.3 objectives and desired outputs

26 June 2008 1

## Concurrence

- General points of concurrence
  - Maintain consistency with Chemical, Biological, and Nuclear models as feasible
    - No modeling of medical intervention
    - No inclusion of battle stress cases
- General modeling concept – human response can be estimated using specified severity levels as occur on injury profiles
  - Nuclear irradiation progressions will be used (including changes as incorporated) for whole body absorbed days
  - Skin (radiological) progressions concurred to with changes
  - Methodology for combining skin and irradiation symptoms to produce injury profile
  - Include time-to-death calculation (green line)



## Concurrence (cont'd)

- Dose/insult ranges with corrections
  - Radiation: as agreed to previously
  - Cutaneous: no corrections
- Symptoms systems
  - Rename "Contamination" as "Cutaneous" to capture both irradiation and contamination
- Symptoms descriptions
  - Remove "Signs" from descriptors
  - Skin (radiological):
    - Modify "Mild" – remove "redness" and "sense of heat", add erythema
    - Modify "Severe" – skin necrosis (remove "possible")

## Additional Tasks

- Participants –
  - Provide supporting documentation, studies, & references as available
    - Holt – 2 sources
    - McClellan – dose protraction curve
    - Wilkinson – Iodine source for inclusion
  - Review Skin (radiological) injury progressions with National SMEs (22 July)
- OTSG/IDA –
  - Incorporate comments as provided for Read-aheads
  - Prepare updated injury progressions and profiles for National reviews
    - Send updated profiles out for review (8 July)
  - Incorporate National comments as provided for updated profiles



## Additional Tasks (cont'd)

- OTSG/IDA (cont'd) –
  - Update the system symptom severity descriptions as discussed
  - Update the injury progressions and profiles as noted
  - Incorporate scaling factor for fallout case calculation (protraction)
  - Add note regarding the necessity to run simultaneous conventional casualties model
  - Incorporate inhalation action level with associated capture of WIA (PREP) at 0.02 Gy
  - Update assumptions:
    - Add CDC assumptions for cutaneous injury
    - Change assumption to read that "activity deposited on the ground will be used to estimate activity deposited on the skin; deposition on the skin occurs by some mechanism (i.e. reaerosolization, etc)
    - Remove "post-fallout field" assumption
    - Add statement that cloudshine dose will be neglected for fallout
    - Update dose protraction assumption to explain incorporation of scaling factor
    - RDD deposition may be discontinuous; may be necessary to represent as point sources

## Additional Tasks (cont'd)

- OTSG/IDA (cont'd) –
  - Notations to be added:
    - Additional notations as discussed



## AMedP-8(C) Study Timeline

- SD.3 (Describe algorithms and required parameters for human response models)
  - Custodial Meetings--review technical aspects of modeling human response with national Subject Matter Experts
    - 21-22 April 2008, Chemical agents (Munich, in conjunction with German Medical Chemical Conference)
    - 8-9 May 2008, Biological agents (San Lorenzo de El Escorial, in conjunction with 21st BioMedAC)
    - **23-27 June 2008, Nuclear effects & Radiological agents (Albuquerque, New Mexico)**
  - September 2008, "Virtual Custodial Meeting" for final pre-coordination review of CBRN casualty estimation (by correspondence)
  - November 2008, Publish SD.3 for review
  - February 2009, Custodial Meeting in conjunction with CBRNMedWG Meeting to adjudicate SD.3 comments and discuss input to NATO conventional casualty estimation tools (Brussels)

# Questions?

## Contact

Kevin G. Hart, CHP

MAJ, MS
CBRN Staff Officer
ATTN: DASG-HCF
5111 Leesburg Pike, Suite 401A
Falls Church, VA 22041-3258
Fax: (703) 681-4971

kevin.hart@us.army.mil
(703) 681-8185

THIS PAGE INTENTIONALLY LEFT BLANK

| REPORT DOCUMENTATION PAGE | | | Form Approved OMB No. 0704-0188 |
|---|---|---|---|



| 1. REPORT DATE (DD-MM-YY) | 2. REPORT TYPE | 3. DATES COVERED (From – To) |
|---|---|---|
| August 2009 | Final | |

**4. TITLE AND SUBTITLE**

Proceedings of the NATO Radiological Human Response Subject Matter Expert Review Meeting, 26 June 2008, Albuquerque, New Mexico, United States of America

**5a. CONTRACT NO.**

DASW01-04-C-0003

**5b. GRANT NO.**

**5c. PROGRAM ELEMENT NO(S).**

**6. AUTHOR(S)**

Julia K. Burr, Carl A. Curling, Deena S. Disraelly, Preston J. Lee, Terri J. Walsh, Robert A. Zirkle

**5d. PROJECT NO.**

**5e. TASK NO.**

CA-6-2281

**5f. WORK UNIT NO.**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**

Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311-1882

**8. PERFORMING ORGANIZATION REPORT NO.**

IDA Document D-3885

**9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

Office of the Army Surgeon General
ATTN: DASG-HCO (MCOP-P)
5111 Leesburg Pike, Suite 401A
Falls Church, VA 22041-3258

**10. SPONSOR'S / MONITOR'S ACRONYM(S)**

OTSG

**11. SPONSOR'S / MONITOR'S REPORT NO(S).**

**12. DISTRIBUTION / AVAILABILITY STATEMENT**

Approved for public release; distribution unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**

In June 2008, NATO subject matter experts met in Albuquerque, New Mexico, United States of America to discuss an approach to modeling human response and casualty estimation for incorporation into NATO Allied Medical Publication 8, *NATO Planning Guide for the Estimation of CBRN Casualties*. The purpose of this conference was to review the proposed human response model for estimating casualties resulting from exposure to radiological agents released through a radiological dispersal device or nuclear fallout. Particular attention was focused on severity definitions and the dose-based injury profiles for two routes of exposure—whole-body radiation and cutaneous (skin) radiation. During the conference, participants reached consensus on the radiological human response model and the injury profiles for use in the document. The presentations and consensus points reached during the NATO Radiological Human Response Subject Matter Expert Review Conference are summarized herein. This conference was sponsored by the US Army Office of the Surgeon General (OTSG).

**15. SUBJECT TERMS**

Modeling, human response, casualty estimation, radiological warfare, radiological hazard, radiological dispersal device, RDD, fallout, whole body radiation, skin radiation dose, radiological contamination, groundshine, cloudshine, protracted dose

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NO. OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | LTC Craig Moss, USA |
| U | U | U | UU | 124 | 19b. TELEPHONE NUMBER (Include Area Code) |